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ON THE FORMS OF TEETH FOR GEAR WHEELS.

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THOUGH the curves which may be employed for the outlines of mathematically correct gear teeth are infinite in number, varying greatly in external appearance, yet all of them must conform with one general principle, viz.: *tooth curves must transmit, from one shaft to the other, the same motion as would the pitch lines when acting by simple rolling contact.*

This truth is, in reality, axiomatic; and for the present purpose needs no discussion or comment. It forms the basis of the present investigation, the object of which is to show how the curves may differ, and the adaptation of certain ones for special purposes.

In this article the terminology indicated below is adopted.

The *pitch lines* of a pair of wheels are lines which pass near the mid-height of all the teeth, and separate the faces from the flanks. These lines must always exist, whether the wheels are designed with regard to them or not, and on which the tooth spaces of one wheel equal those of the other.

The *face* of a tooth is that part of the outline of one side of a tooth which extends from the point or top of tooth to the pitch line.

The *flank* of a tooth is that part of the outline of one side of a tooth which extends from the pitch line to the bottom of the space between two adjacent teeth. The length of this, reckoned in the direction of a radius, is usually made a little greater than the length of the face, similarly measured, to allow for *clearance.*

The *pitch* is the distance, reckoned on the pitch line, from a point on one tooth to the corresponding point on the next.

The *velocity-ratio* is the ratio of the angular velocities of the wheels, and may be constant or variable. If constant, it is equal to the number of revolutions per minute of one wheel, divided by the same for the other.

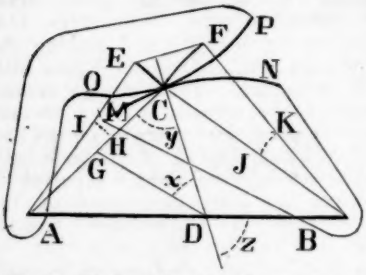
In the study of gearing two kinds of contact are considered, viz.: rolling contact and sliding contact. The former takes place between the pitch lines, and the latter between the curves forming the outlines of the teeth. When the pitch lines are not circular, the problem of determining them so as to give true rolling contact, with fixed axes, is quite extensive. The present paper is confined to the outlines of teeth, the pitch lines being supposed given.

In the figure, let A and B represent the centers of a pair of gears, and M N and O P the curves of a pair of teeth in action. The point of contact C is chosen

at one side of the line of centers, so as to represent the general case.

Now, suppose the wheel A to swing through the small angle C A E. The

FIG. 1.



point C will describe the elementary arc C E. At the same time the wheel B, to maintain contact with A, must move through the elementary angle C B F, and C through the arc C F.

To determine C F, it is sufficient to note that as the movements of the wheels are elementary, the common tangent to the curves at C will scarcely change its inclination appreciably. Therefore, the end of the radius B C will be found at F, in a line, E F, parallel to the common tangent.

Draw a common normal C D to the curves. It will be perpendicular to E F. Then the velocity-ratio may be obtained as follows:

At a unit's distance from A and B draw H I and J K respectively. These arcs will serve to measure the angular velocities of the wheels, and hence:

$$\text{Velocity-ratio} = \frac{HI}{JK}.$$

The triangle C E F is similar to C D G, and hence:

$$AH : AC :: HI : CE$$
$$BJ : BC :: JK : CF$$
$$CE : CF :: CG : DG$$
$$DG : BC :: AD : AB$$
$$CG : AC :: BD : AB$$

Whence, observing that A H = B J = unity,

$$\text{Velocity-ratio} = \frac{HI}{JK} = \frac{EC}{AC} \cdot \frac{BC}{CF} = \frac{CG}{DG} \cdot$$
$$\frac{BC}{AC} = \frac{AB}{AD} \cdot \frac{BD}{AB} = \frac{BD}{AD} = \frac{V}{v},$$

if V and v represent the angular velocities of A and B.

Hence, when rotary motion is transmitted from one shaft to another by sliding contact as in gear teeth, the angular velocities are to each other inversely as the segments, or parts of the line of centers, formed by its being cut by the common normal to the curves.

It is to be observed that at the end of the movements C E and C F, the points which were in mutual contact at C are now removed a distance E F; and as this displacement was accompanied with slipping, the amount of the latter is E F. In the similar triangles C E F and CDG, we have the same relation between E F and C D, as we have between C E and C G, or C F and G D. Hence, E F can only be zero when C D vanishes; or when the point of contact is on the line of centers. For this, the contact has changed from sliding to rolling; and, therefore, for rolling contact, the angular velocities are inversely as the radii of contact. In circular wheels the velocity-ratio must remain constant, because these segments are constant; whereas, in non-circular wheels it is variable. In the former, the point of contact remains fixed, while, for the latter, its position varies along the line A B.

The contact of a pair of teeth must continue for a time, at least, long enough for the next pair of teeth to come fairly to contact; or, long enough for the pair of teeth to move through a space as great as the length of the pitch. This contact cannot therefore be confined to the line of centers, and hence sliding

* This geometrical solution is essentially the same as that given in Belanger's most excellent work on Cinematique, page 90, where also the velocity of sliding is found to be proportional to C D.

Those familiar with Trigonometry may prefer the following trigonometrical solution. We have

$$CE = AC \cdot V, \quad CF = BC \cdot v,$$
$$CEF = \text{angle } y, \quad CFE = x, \quad ADC = z;$$

and hence:

$$CE \sin. y = CF \sin. x,$$
$$AC \sin. y = AD \sin. z,$$
$$BC \sin. x = BD \sin. z,$$

or
$$V \cdot AD \sin z = v \cdot BD \sin. z,$$

and
$$\frac{V}{v} = \frac{BD}{AD},$$

as before.

of the curves upon each other is unavoidable*.

From the preceding discussions it follows that in all gear wheels, circular or non-circular, the common normal to the sliding curves, and the pitch lines, must both maintain a common point of intersection with the line of centers; and this condition is the only one necessary for fulfilling the general principle stated at the outset. The common normal, because it is the line of action of the pressure between the teeth, friction neglected, and, for its importance otherwise, is called the *line of action*.

Suppose, for example, any curve whatever, as *b a c* Fig. 2, be taken as the

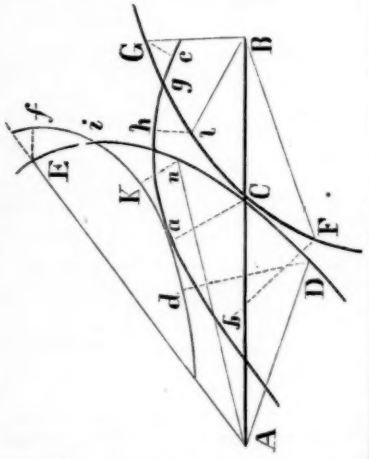


Fig. 2.

form of the side of a tooth of a gear wheel revolving about B. Then let the curve *d a f* be found for the side of a tooth of A, which, acting by sliding contact on *b a c*, will give to A the same angular motion as that transmitted by the rolling curves D E and F G, the latter being supposed circular or not. Let D and F be two points of the rolling curves which come to mutual contact on the line of centers, and similarly for E and G. Then arc C D = arc C F, and arc C E = arc C G, &c.

Now for the present point of contact C of the pitch lines there must be a point of contact of the tooth curves, and because the common normal to those curves must meet A B in C, we simply draw C *a*, normal to *b a c*. This is the present point of contact of the tooth curves, and hence a point of the curve sought. To find another point, draw F *b* normal to *b a c*. Then draw D *d* equal in length to F *b*, and making the same angle with A D, that F *b* does with B F prolonged. Then, *d* is a second point of the required curve; because when D and F are in contact on the line A B, D *d* and F *b* will coincide in length and direction, with *d* and *b* superposed, forming the point of contact of the tooth-curves. In like manner *f*, and indeed any number of points may be found. The curve *d a f*, traced through these points, is the desired curve.*

In the above example, A and B are supposed to be the centers of rotation, in which case D E, and F G, must be a pair of correct rolling curves. But the solution is still more general. Any two curves whatever, without fixed axes even, may be used for the rolling curves, and the sliding curves determined. When radii do not exist, tangents to the rolling curves may be used to reckon the angles by. Such a case, however, would but rarely occur in practice.

This solution indicates that one tooth curve may be assumed, and the other formed as a dependence. It fails, however, as being both theoretically and mechanically impossible, and so with any theory, when the normals C *a*, F *b*, &c., will not strike the pitch line.

Though one tooth-curve may be assumed and the other determined, the theory admits of other solutions; the most common being by aid of *describing* curves, called also *generating* or *tracing* curves. In this case the describing curve is assumed and both tooth-curves made dependent. To show that this solution depends upon one and the same general theory, let us find a describing curve which will generate the tooth-curve *b a c*, or *d a f*.

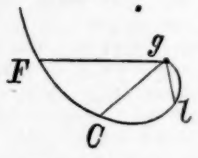
In Fig. 3 draw *g l* equal to *h l*, Fig. 2. Then take *l* C, Fig. 3, equal *l* C, Fig. 2. Also *g* C, Fig. 3, equal *a* C, Fig. 2. And again C F and *g* F, Fig. 3, equal C F and *b* F, Fig. 2, respectively, &c., for as

* Hooke's spiral gearing admits of contact which may be confined to the plane of the axes, and hence free from slip. But this is due, not to the form of tooth, but width of wheel face; or, length of wheel in direction of axis.

* This solution given in Belanger's Cinematique, p. 97, appears to be due to De la Hire; and given by him as early as 1694. See Willis' Princ. Mechanism, 2d ed., p. 89.

many points as desired. Then trace the curve $g\,l\,C\,F$, Fig. 3. This is the describing curve sought. Now suppose this curve be placed in contact with F G, Fig. 2, so that g, Fig. 3, falls at g, Fig.

FIG. 3.



2. Then by rolling the describing curve along toward F, the points l, C F, Fig. 3 will exactly fall at l, C F, Fig. 2, because the arcs $g\,l$, l C; C F, are equal in the two figures. Also the construction makes $g\,l$, g C, g F, &c., intersect the arc of the describing curve at the same angles that the normals $h\,l$, a C, b F, &c., intersect the pitch line, which is easily seen to be true by supposing the points g, C F, &c., very numerous. Hence the radii vectors of Fig. 3 will successively come to exact coincidence with the normals of Fig. 2, and at the same time g will trace out the very curve $g\,h\,a\,b$.* And similarly, by rolling the same curve from i to D, Fig. 2, the curve $i\,k\,a\,d$ will be traced. In like manner a describing curve can be produced which will generate, by rolling from g or i toward G or E, the remaining portions $g\,e$ and $i\,f$ of the tooth-curves.

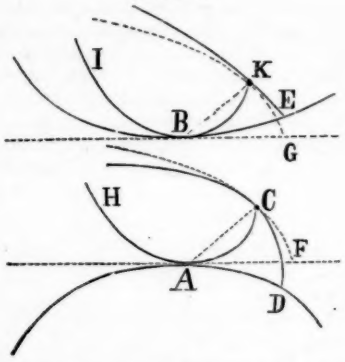
Thus it appears that a generating curve can always be found that will trace out a given tooth-curve. But whenever the latter are neither of them fixed, we are at liberty to assume a describing curve, and this may be of any form whatever which may admit of rolling on the pitch lines. The two solutions are therefore one and the same, the difference being simply in the part assumed. And within this are comprehended all known forms of gearing, such as involute, epicycloidal, epitrochoidal, pin-gearing, Prof. Edward Sang's hour glass curve gearing, &c., &c.

The solution of the problem is therefore reduced to simply this; any describing curve rolled upon the outside of one pitch line, and upon the inside of the other pitch line, beginning at mutual contact points; will describe a pair of faces and flanks which will work correctly.

This may be demonstrated by a direct graphical method as follows.

Take pitch lines A D and B E, circular or non-circular, and a describing curve C A H; or, which is the same, K B I. Also take D and E as the pair

FIG. 4.



of mutual contact points, where the pair of tooth-curves sought begin. Let C A H roll in outside contact from D to A, describing D C by a tracing point C; and similarly rolling the same curve from E to B, describes the curve E K. This rolling may be continued to any extent, giving the full line curves D C, and E K produced.

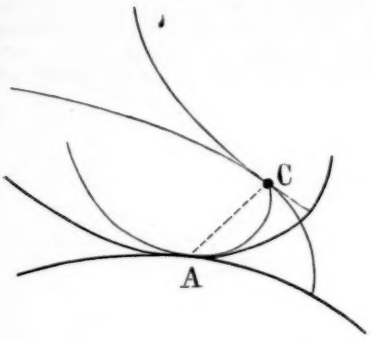
If the same curve be rolled on tangents at A and B, two equal curves will be described which are shown in dotted lines. Let arc D A = arc E B = arc C A = arc K B = A F = B G. Then chord A C = chord B K, and angle C A F = angle K B G. Hence if A and B be placed in tangential contact, the tangents and dotted curves will coincide precisely; and the full line curves, or tooth-curves, will have a point of tangency at C K. Also the curves will not pass, one to the opposite side of the other, because the full line curve for A lies wholly below, and for B wholly above the mutually coinciding dotted curves. This being true for one point taken at random must be true for all, giving the precise conditions required for tooth-curves.

We might suppose for illustration that the three curves roll upon each other with one point A in common tangency.

* De la Hire, in 1733.

The tracing point C, would then trace, simultaneously, the two curves shown,

FIG. 5.



one upon the plane of each wheel, and which will serve to work correctly as a face and flank.

We are now prepared to draw the following conclusions :

1st. The faces and flanks all have their origins at the pitch line.

2d. Each face and flank couplet must be generated by rolling the tracing curve in the same direction, on the outside of one, and inside of the other pitch line.

3d. The contact of a couplet is confined to one side of the line of centers.

4th. Couplets which do not interchange flanks and faces may be generated by different describing curves ; even though on the same pair of wheels.

Different describing curves give different forms of gear teeth, some of the most important of which will now be considered.*

In practice the pitch lines are usually circular; though on shaping and slotting machines, and others requiring a "quick return," non-circular wheels have been employed with advantage. In Fig. 6 is given such a pair of non-circular wheels, drawn carefully to a scale, with each tooth-curve worked out for its particular position by the general theory.† The describing curve used was a circle, the diameter of which was about one-third that of the pitch line of A. These wheels were designed with special reference to adaptation for shaping and slotting machines, in which the tool is reciprocated by a crank and pitman. The forward stroke is uniform, except for one-fourteenth at each end, given for slowing down for passing the center. The return is accomplished in one-half the time the entire forward stroke requires. The teeth are made large, proportionately, for the purpose of illustrating the fact that such wheels require teeth which differ from each other in form.

Circular wheels form only a special case of the general theory ; but as these are of almost exclusive use in practice, with the teeth varied for different purposes, the following important classes will be considered separately, viz.:

I. Wheels with epicycloidal teeth ;
II. Wheels with involute teeth ;
III. Wheels with random teeth.

Epitrochoidal curves have been suggested for tooth-curves, but as they do not admit of tooth-contacts near the line of centers, where most desirable, they are not useful for general purposes.

I. EPICYCLOIDAL GEARING.

This name is applied because the tooth-curves are epicycloids and hypocycloids. An epicycloid is traced by a point upon the plane of a circle, when that point is guided by being attached to the circumference of a second circle which rolls upon the first. If external it is an epicycloid, if internal an hypocycloid.

A curious fact relating to these curves deserves notice, viz. : that every epicycloid and hypocycloid admits of being generated by two different rolling circles. To illustrate, suppose A $b\,c$ to be a primitive or pitch circle, and B a rolling or describing circle, tracing with p the epicycloid D, by rolling on A. Draw the line $p\,b\,c$ through the point of tangency b. Then $b\,p$ will be a normal to the epicycloid at p, because an elementary part of the latter is described while b serves as an instantaneous axis for the wheel B to turn about. Now, this elementary portion of D will be the same if c be the center instead of b. This being true for each elementary part of D, it follows that a circle C, tangent at c, and having a tracing point p, will trace the same epicycloid that B will. It can be easily

* It may be observed by comparing Figs. 2, 3 and 5 that the generating curve must lie on the opposite side of the pitch line from where the intersections of the normals are found. From this it follows that if these intersections cross the pitch line as the rolling proceeds, so must the describing curve. The latter will then change its direction with a cusp.

† Drawn by a former pupil, Mr. Emory Patch.

FIG. 6.

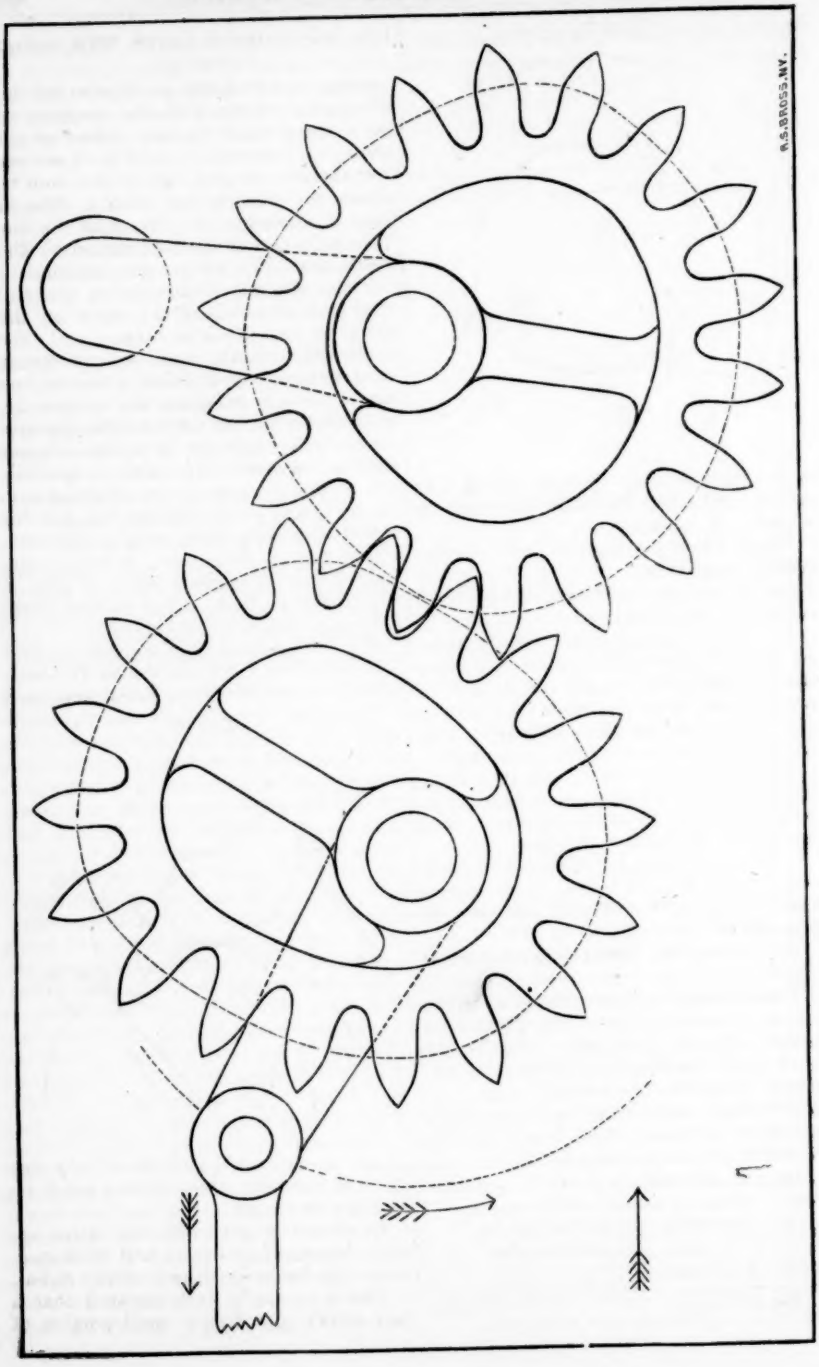
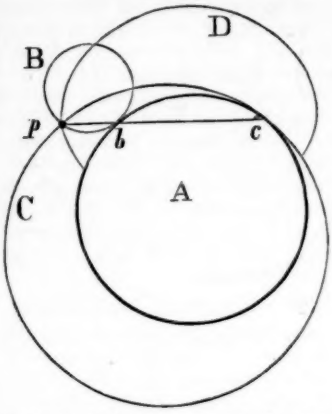


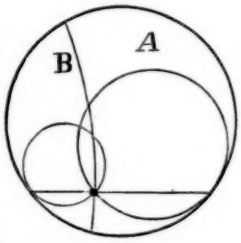
FIG. 7.



shown that the difference of the diameters of C and B is equal to the diameter of A.*

Fig. 8 indicates how this double generation applies to the hypocycloid, in which A is the pitch circle and B the

FIG. 8.



hypocycloid. The sum of the two diameters of the generating circles evidently equal the diameter of the pitch circle.

That the teeth be mechanically possible, it is necessary that the generating circles be as small, or smaller than the pitch circles within which they roll; otherwise the teeth would collide.

This range in the relation of sizes gives variety of form of teeth, the following of which are the most essential: .

1st. Flanks radial.
2d. Flanks parallel, for strength.
3d. For minimum of friction.
4th. For change-gears and sets.
5th. Pin gearing.

* Due to Duhamel, see Bour Cours de Cinematique, p. 120.

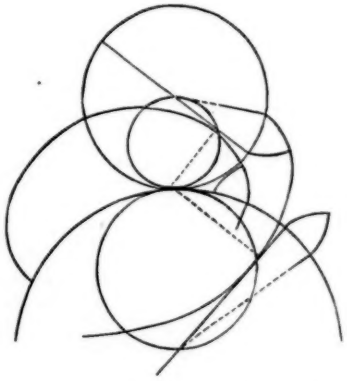
1ST. EPICYCLOIDAL TEETH WITH RADIAL FLANKS.

Suppose a generating circle to roll inside a pitch circle, with the diameter of the former equal to the radius of the latter. By reference to Fig. 8 we see that the two generating circles would be equal, and the hypocycloid a straight line, a diameter of the pitch circle. This principle is the foundation of the well-known White's parallel motion.

Hence when the diameters of the generating circles equal the radii of the pitch circles in which they roll, the flanks will be radial, and very convenient to construct. In practice, therefore, we have simply to delineate the epicycloids, with circles half as large as the opposite pitch circles, and strike in the tangent radii for flanks. This form of gearing is the most convenient for practical execution of any good form known, and for this reason is the form usually adopted, when correct delineation is attempted. Indeed many designers have no idea of the existence of any other correct form, except, possibly, the involute.

Fig. 9 represents the simultaneous generation of the faces and flanks for both wheels, the four circles being supposed

FIG. 9.



to roll upon each other with only one point in common, each tracing point describing two lines.

In wheels of few teeth, the latter appear somewhat undercut, and weakened, when the flanks are drawn wholly radial.

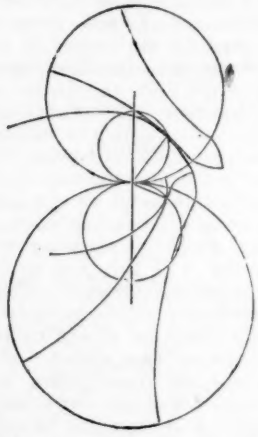
But it is easily demonstrated that a face works upon only a small portion of

the flank, which also is adjacent to the pitch line. Below this the teeth may be thickened by clearance curves, almost entirely removing this objection. An advantage is gained by these teeth which probably more than compensates for the above objection. This consists in the great freedom from crowding of the wheels from each other, due to the near approach of the line of action to the perpendicular to the line of centers; and this is evidently necessary for most favorably transmitting the rotative forces from one wheel to the other. For instance if the line of action be made parallel to the line of centers no rotative effect is secured.

2D. FLANKS PARALLEL.

By employing smaller generating circles than in the above, the flanks may be rendered more nearly parallel as shown in Fig. 10; and the basis of the teeth

FIG. 10.



thickened as required for strength. Clearing curves may still be introduced for further strengthening of the teeth. No rule of proportions is prescribed: in each case the diameters of the rolling circles must be determined by the judgment of the designer.

The flanks are only approximately parallel, because, in reality, they are the slightly curved hypocycloids. But for that small part against which the faces act, a straight line may be substituted without sensible error.

The rolling circles being smaller than for the case of radial flanks, the epicycloids will be smaller for the same pitch lines, and hence the points of the teeth narrower. This results in a greater general inclination of the side of a tooth to a radius, causing greater inclination of the line of action from the perpendicular to the line of centers inducing increased lateral crowding, and consequently friction. In a long train of gearing it is therefore doubtful whether this form of tooth is any safer than the preceding, because with greater strength there is greater resistance.

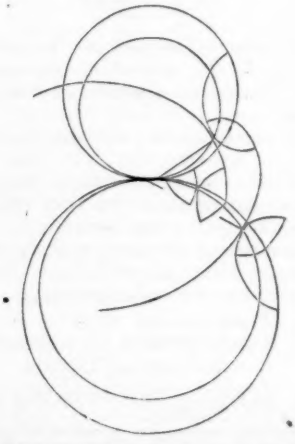
3D. FOR MINIMUM OF FRICTION.

From the preceding examples, it appears that the friction is reduced by approaching the line of action to the perpendicular to the line of centers. The line of action in epicycloidal teeth being the chord to the generating circle which connects the describing point with the point of rolling, it appears that the most favorable condition is secured by making the generating circles large as possible.

Again the generating circles, when situated as in Figs. 9, 10 and 11, form the path of the points of contact in their journey from the point of beginning, to the point of quitting contact, one circle for one side and the other for the opposite side of the line of centers; so that large circles, in both senses, appear most favorable.

Fig. 11 presents these conditions, and

FIG. 11.



indicates that the teeth are very much

undercut; indeed, in extreme cases, entirely cut off by reason of the convex faces, due to the excessively large rolling circles.

It is evident that such teeth cannot be used where great strength is required, as in mill-work; but where the resistance is slight, and smoothness of motion and freedom of action are requisites, as in horology, this form may be used with great advantage. Fig. 12 is a careful

FIG. 12.

drawing of such a pair of wheels, with teeth much undercut.

4TH. CHANGE GEARS AND SETS.

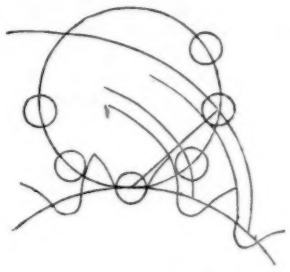
The most common use of change gears occurs with the machinist's engine lathe for screw-cutting. In this, and most other cases requiring such wheels, the teeth are small; and when only approximate, occasion no especial inconvenience. But sets sometimes occur in mill-gearing where correct forms of teeth are necessary.

For such cases it is only needful that *one* generating circle be employed for the whole set.* This circle should not be more than half as large as the smallest wheel of the set. The teeth of the latter will then have radial flanks, while those of all the others have concave flanks and thick bases.

5TH. PIN GEARING.

By increasing the generating circle, Fig. 11, the hypocycloid decreases until, when the former coincides with the pitch circle, the latter becomes a point, the tracing point itself. Then the theoretical teeth are points for one wheel, and for the other epicycloids generated by the opposite pitch circle as shown in Fig. 13. In practice the points are en-

FIG. 13.



larged to pins of cylindrical form, and the teeth reduced to lines parallel to the epicycloids and distant from them a space equal to the radius of the pin. Such wheels are sometimes called pin gearing.

These wheels should work smoothly, because the line of action is suitably situated for a minimum of friction, but they are not free from objection for having the tooth contacts all on one side of the line of centers. These one-sided contacts serve best when the pin wheel is driven, and in this way this gearing is much used in modern clock-work. The pinion, called *wallower*, *trundle* or *lantern wheel*, is usually made for clocks by inserting wires between two collars; while the wheels are cut from plates, many of which are stacked and cut at once.* In this way should the wheel be quite thin, and wabble, the trundle may have sufficient length of pins to accommodate. Such gearing is cheaper than thick cut gearings, and may explain its introduction into the inexpensive, though very good, American clocks.

But it is probable that the very best conditions for clock and watch gearing would be secured by a sort of *cross* between Figs. 11 and 13, represented in Fig. 14. The generating circle should be so large that the hypocycloid, for

* This solution was first given by Prof. Willis, see Princ. of Mech., 2d ed., pp. 87, 118, and 136, the latter as in connection with the Willis Odontograph.

* In the full sense of the term *pin gearing* the wheel teeth are also pins set into the edge of a disk.

both pitch lines, spans a breadth just sufficient for the tooth thickness, and the

FIG. 14.

whole hypocycloid taken as that part of a tooth, or pin, which lies within the pitch line. The balance of the tooth should then extend outward, to a point, similarly as in Fig. 11. Thus contacts will be secured on both sides of the line of centers, as required, with the nearest approach of the line of action to the perpendicular to the line of centers consistent therewith.

These wheels could be constructed by inserting suitably formed pins by one end into disks, and projecting toward each other from the two wheels; or, by supporting the teeth upon slender necks, as shown, which is possible, because only small parts of the hypocycloids are brought into contact with the faces.

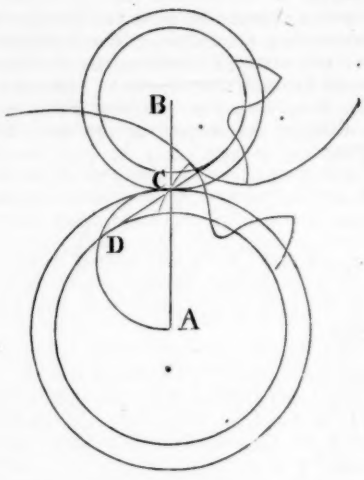
It is plain that if the line of action could be straight, and perpendicular to the line of centers, the wheels could be approached or withdrawn without causing great changes of conditions of action of the teeth. The form, Fig. 14, with teeth supported upon clearance curve-necks, would, therefore, be one of the best for this purpose, and nearly the same as found on the rollers of clothes-wringing machines, &c., as arrived at, probably, by the demands of practice.

II. INVOLUTE TEETH.

The involute curve is a special case of the epicycloid in which the generating circle is infinite.

Let A and B represent two pitch circles in contact at C. Draw any inclined right line through C and two circles tangent to it with centers A and B. These are taken as the base circles for

FIG. 15.



involutes. The ratio of the radii of these circles will be equal to that of the pitch circles. Suppose the inclined line, C D, be produced, and wound upon the base circle A; and also separated near C, with a tracing point attached. As the string is unwound, the tracing point will describe an involute which may be taken for the side of a tooth of A as shown. A similar unwinding from B will describe the involute tooth-curve for it. It is plain that the contacts will all lie on the inclined line C D, because it will cut normally all the involutes described on the bases A and B. This is at once the line of action, and locus of the points of contact.

In the present case the line of action is inclined more or less, at pleasure, but must always pass C. This change of inclination may follow from varying the diameters of either the pitch or base circles. The former corresponds to changing the distance between the axes of the wheels, which these gears are well known to admit of, and work correctly. But when the distance is considerable, the teeth become monstrous thick at base, and objectionable; and unsuited for such purposes as clothes-wringers. The contact for these teeth is only possible between the points of tangency

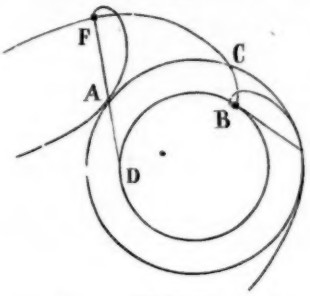
of the line of action with the base-circles. Hence, by enlarging the base-circles, these limits are constricted, and, finally, vanishing when the line of action becomes perpendicular to the line of centers, giving no contact. The best condition is a matter of judgment, and the designer must choose between objectionably few contacts, and objectionable inclination of line of action and thick teeth.

The contact being confined to the line of action, limited as above, it is plain that no bearing can occur upon a tooth below or inside the base circle, and usually clearance curves are arbitrarily struck in to give the necessary depth for receiving the points of the teeth of the other wheel.

One fact is worthy of note, serving to put these wheels in comparison with the epicycloidal. If a circle be struck with A C as diameter, it will always pass the point of tangency D. That point, in involute gearing, is the limit of contact of teeth; but not in epicycloidal gearing with radial flanks, though that will be one position. Intermediate between D and C the contact for involutes is on the line C D; and for epicycloids, on the arc C D. The line of action in the latter case will vary from a perpendicular to A B, to the inclination C D, while the point of contact moves from C to D. Hence, the average inclination of the line of action between C and D is much more favorable in epicycloidal gearing than involute, from which it appears that the former is the preferable form of gearing.

Fig. 15 may appear to furnish an example which is inconsistent with our general theory, because the generation is effected by rolling the describing curve or line on the base circle instead of the pitch line. But this is reconciled thus: In Fig. 16 take a pitch circle A C, base circle B D, describing line D F, with describing point F, and a log. spiral F A. Now as the describing line unwinds, tracing the curve C F, the line will cut the pitch circle at various points A at a constant angle, which follows from the concentricity of the pitch and base circles. As the radius-vector makes a constant angle with the arc of a log. spiral, if that angle at A, be the same as D F with the circle at A, then the radius vector F A will coincide with the line D F continually, and the tracing point will describe one and the same curve whether carried by the spiral F A or line F D. This curve begins at C. To supply the remaining part C B roll the same spiral

FIG. 16.



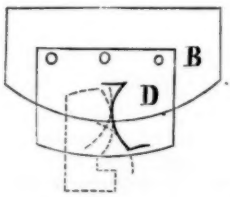
inside as shown. This description will stop at B for the reason that the log. spiral then bears on the inside of the circle where its curvature equals that of the circle. Hence this is explained by the general theory, and the wheel has true flanks and faces, separated by the pitch line, as usual.

III. RANDOM TEETH.

These might be styled *random teeth* because a tooth-curve for one wheel is drawn at random, or at least arbitrary, and the form of tooth for the other wheel found from it. The solution on the drawing board is the same as Fig. 2, and hence, it is in keeping with the general theory of the teeth of wheels. It would need no further consideration except for the exceedingly advantageous practical process for obtaining the second curve, first made known by Prof. Willis in 1837.

Let A and B represent the pitch lines, formed by cutting strips to the right curves. A tooth curve C is cut at

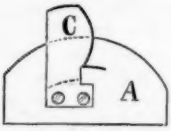
FIG. 17.



pleasure, and mounted on A so that the

card board D may play between A and C. The card board D is secured to B. The pitch lines are then placed in contact as shown by the dotted lines, and a line traced on D, along the edge of C. Then

FIG. 18.



A is rolled on B, without slipping, to a new position, and a second line traced by the edge of C. Thus proceed for various positions. An enveloping curve traced on D will be the required tooth-curve for B.

This process would apply admirably for matching a gear already existing, and no matter if it be worn provided it is regular.

PRACTICAL OPERATIONS.

In actually executing wheel-work, there are certain operations which contribute to the accuracy and dispatch. The draughtsman can draw his tracing curve in several positions, and by stepping with spacing dividers arrive at several points in the desired tooth-curves. But in thus measuring off distances on arcs, errors occur in that the dividers measure chords instead of arcs. Also each placing of the divider points involves a small error depending upon eye-sight, precision of draughtsman, &c., Again several operations, following and depending upon each other, between the theory and the result, entail cumulative errors, sometimes so great, that the result obtained scarcely resembles the truth. The fewer the intervening operations, the less will the truth be adulterated with error.

Templates are valuable because they secure a more direct relation between the theory and final tooth-curves. In some instances a still closer relation has been obtained. To illustrate, the templates give the curve, and then the teeth or cutters are to be formed from it by an eye-and-hand process. But in some watch-works, epicycloidal machines are used in which the cutters are formed direct from the rolling curves. These cutters however are *master cutters* from which the working cutters are formed. But this last operation admits of great precision.

In Fig. 17, the pieces A and B are called pitch templates and a piece cut to the form of the describing curve as in Fig. 3, is called a describing template.

By a set of such templates the operation represented in Fig. 4 may be undertaken. Tooth-curves may thus be drawn on metal plates, and subsequently cut carefully to the line. Such a pattern may be used for turning up a cutter by, or for marking out the teeth on a gear pattern of wood. In the latter case, it may be called a scribe template. And it is convenient to mount this upon a rod attached to swing around a center pin to the gear. Either of these operations involves two eye-and-hand processes, as, for instance, dressing up the scribe template; and then turning the cutter by it. But it is not convenient to reduce the number further, though, by aid of an *odontograph*, described in the July number of the Magazine, the inconvenience of resorting to pitch and describing templates, is avoided from the fact that the odontograph serves as a ready-made scribe template, as exact as a special scribe template laid out and dressed up, as above described, would be, and which is also adapted to being mounted to swing around the center of the gear.

THE AMMONIA PROCESS OF TREATING ORES.

From the "London Mining Journal."

SOME fifteen months since an improved process of treating ores and minerals for obtaining gold, silver, and other products therefrom, was suggested by Dr. Thos. Clarke, of Wilmslow, and Mr. E. Smith, of Torquay; and enough has now been ascertained with regard to the invention to permit of an opinion being formed upon its merits. Mr. Smith explains that, briefly, the process consists in the

solution of the copper and silver salts, after calcination of the ore, by means of ammonia and ammoniacal salts, then passing this solution through a galvanic tank, formed by a suitable and economical arrangement of sheets of platinum and copper, by which means the whole of the silver is deposited in practically a pure state, whilst the copper passes on—still in ammoniacal solution—and is precipitated as oxyd, by passing steam into the solution, with the simultaneous addition of a very small amount of caustic alkali. This not only precipitates the copper as oxyd, but drives off the ammonia, which may be collected for re-use. The special advantages which he claims for the ammonia process are chiefly its economy and simplicity, and the purity of the products obtained.

In carrying out the process, the ores or minerals to be operated upon having been first sorted, if necessary, are pulverized or ground and sifted to the requisite degree of fineness and uniformity of size, and then thoroughly washed and elutriated, so as to separate all the light sparry, silicious, and earthy substances from the heavier mineralized matter, and concentrate the really valuable portion to the utmost possible extent. The specific gravity of the gangue, or non-mineralized part, never averages above 2.9, and if not removed clogs and harasses all the succeeding operations. This removal is effected by their improved buddle. The heavier and concentrated material thus obtained is then roasted, if necessary, to expel volatile substances, such as arsenic and sulphur, and which may be collected and purified in any ordinary manner. It is then mixed with an alkaline chloride, such as common salt, in the proportion suitable to each class of ore, say in the ratio of ten per cent., and chlorodized in any ordinary furnace. As the process of roasting and chlorodizing as now performed is very slow and tedious, they propose to shorten the operations by passing a cold or hot blast of air, which can be regulated at will, through one or more openings in the furnace, whenever it may be considered requisite. If the chlorodized material when cold is lixiviated with water the salts of gold, copper, iron, &c., are dissolved, whilst tin, if present, is untouched, and only a portion of the chloride of silver is dissolved, the amount so dissolved depending on the temperature of the water used for lixiviation. If cold water is employed the chloride of silver is nearly insoluble, whilst the metallic salts above referred to are readily soluble. The solution thus obtained, which also contains all the free acid (and which it is essential should be removed), being duly heated by steam-jets, or superheated steam, or otherwise, is deprived of its copper by being digested with scrap or other form of iron in a suitable tank in the usual way.

The deposit of copper thus obtained may also contain a small portion of gold or silver which may have been dissolved by the cold water. The residue left after lixiviation; and containing the chloride of silver (and if the ore has been imperfectly or improperly chlorodized it may also contain compounds of copper) is now treated with a solution of an alkaline hyposulphite, preferably with hyposulphite of soda, or with a solution of ammoniacal gas in water, commonly called caustic or liquor ammonia (purified coal-gas liquor will do); or of a salt containing ammonia, or with a mixture of any alkaline hyposulphite with any of these ammoniacal compounds, in which the chloride of silver as well as the residuary copper compounds are readily soluble; because they have found by careful observation and research that silver is far more quickly and certainly precipitated from alkaline than from acid solutions. The clear solution of silver thus obtained, either by the hyposulphite of soda or with ammonia, separately or both combined, is next run into a tank, in which are placed sheets of copper alone, or sheets of copper in contact with platinum or other suitable metal, carefully arranged. To induce galvanic or voltaic action zinc may also be used instead of copper, but in this case if the silver solution should contain any copper, it will be precipitated with the silver, and so be intermixed with it. Their object, when two metals are used, is to turn the whole tank into a galvanic or voltaic battery.

It is not necessary to use platinum in a solid form, as it will be found sufficient to use it as sheets, foil, or strips, or even as any platinized solid, so that the due

connection between the metals be kept up. This connection causes a very rapid deposition of the silver, and the action is increased by the further addition of ammonia either to the lixiviating or silver precipitating tank, or both ; indeed, so exhaustive is the solvent power of ammonia that it will not only, either alone or in combination with the hyposulphite, dissolve any silver remaining, whether as chloride or oxyd, but it will also dissolve any cupreous chloride resulting from defective chlorodization, and even minute particles of metallic copper. If hyposulphite of soda alone is used, the action may be aided by superheated steam, by passing galvanic currents in connection with the platinum and copper to increase the action going on within the tank, and if necessary by also adding a suitable quantity of ground copper precipitate, derived from previous operations, to the solution. The silver thus obtained may be contaminated with certain compounds of silver or copper, which may be readily removed by washing with ammoniacal liquor or solution of hyposulphite of soda, or both together, such washings to be put back into the silver precipitating tank. The solution after being thus deprived of its silver is drawn off (and if ammonia has been used it may be expelled by the steam jet) and passed into the ordinary copper-precipitating tank, or the ammoniacal solution itself may be passed into a tank, and the copper precipitated by zinc or by zinc in contact with platinum or other suitable metals.

In the case of ores containing silver, but without any or with only small quantities of other metals the chlorodized ores may be at once treated with a solution of the hyposulphite or with ammonia, or with both combined, without any previous lixiviation (except it may be to remove any acid or other impurity), and the silver solution so obtained be passed into the silver precipitating tank in the manner hereinbefore described. It is to be understood that when hyposulphite of soda alone is used any temperature may be employed during any part of the process, but when ammonia, either alone or in conjunction with hyposulphite, is used the process is more economically conducted at ordinary temperatures on account of the volatile nature of the ammonia.

The inventors mention that, although by their improved process they employ agents a little more expensive than those hitherto in use, yet the primary concentration of the mineralized matter, the more perfect exhaustion of the materials treated, and the rapid and independent form of working repay many times over any extra cost. The platinum is, of course, absolutely unacted on by the treatment, and always retains its full market value ; but it is also to be specially observed that in the case of ores containing little silver and copper, and where the excess of salt used in chlorodizing may be found to be a sufficient solvent, or where it is preferred to separate the silver from the copper in smelting rather than by passing the solution through our silver precipitating tanks (as they should advise) the concentrated and chlorodized ore may be at once brought from the furnace, and put into a simpler form of their improved buddle, partially filled with hot water, and there washed or lixiviated until the silver and copper compounds are dissolved. After allowing a little time for settling after each washing the solution may be passed into the filtering tank, or even at once to the copper precipitating tank, when, according to an old and well-known law, the copper, silver, and gold, will, and indeed must, be precipitated together. The precipitate, when enough has accumulated, may be washed in the buddle until all soluble salts, silicious matters, and other impurities are removed, and it is fitted for the market. The residue of the ore is, of course, to be treated for tin should it be present therein.

So much for ores chlorodized in the usual way, but their ammonia process is not thus limited, for chlorodization by salt and subsequent precipitation by iron may be rendered altogether unnecessary, because ammonia with one of its salts added—the chloride of ammonium—forms one of the most powerful solvents for copper and its compounds known. To effect this the ore is roasted in a proper furnace until all the sulphides are decomposed and rendered amorphous (which the microscope readily shows), and it is then plunged, hot or cold, into

water containing chloride of calcium or barium, or both, and left for a time to steep. It is then treated with ammonia, and in the reactions the sulphuric acid unites with the lime, forming insoluble sulphate of lime, which is precipitated. One portion of chlorine forms chlorides with the metals, and the other hydrochloric acid, which, when excess of ammonia is added, forms chloride of ammonium, and so by this simply chemical change the double solvent is obtained. In the case of burnt Spanish pyrites these facts may be at once demonstrated. The copper and silver are thus obtained in a clear solution, the iron and all the other impurities being left behind. The silver may be separated as before, and on the ammonia being expelled by superheated steam jets in a suitable tank the oxyd of copper is precipitated. The addition of a little fixed alkali ensures the precipitation of the whole of the copper, dehydrates the copper oxyd, and causes the expulsion of all the ammonia. This process is not only a very rapid but a very economical one, as (the process being a closed one) the ammonia is readily recovered, whilst the copper and the silver may be smelted on the premises, and obtained in a state of very great purity.

In the case of argentiferous lead ores it is well known that during the metallurgic treatment of such ores the silver is ultimately obtained alloyed with lead, from which it is very imperfectly separated by the process now in use. It is also well known that if metallic zinc be added to the fused argentiferous lead the silver separates from the lead, and forms an alloy with the zinc, the argentiferous zinc so formed rising as a scum to the surface of the molten metal. They extract the silver from this silver-zinc scum by very carefully chlorodizing, either with or without the addition of sand or other inert substances, as may be found necessary; then lixiviating the powdered chlorodized material first with cold water (and if such solution contains silver it may be cast into the silver precipitating tank), and then lixiviating the residue with a solution of hyposulphite of soda or ammonia, or preferably both combined, and passing the silver solution thus obtained into the silver precipitating tank, as previously described. Should tin, however, be present in any of the ores thus treated it is unaffected, as previously observed, by any of the foregoing operations, and may be subsequently dealt with in the chemical and mechanical manner to be now described.

It is a well-known fact that by the present method of dressing ores containing tin, or "tin ores," very considerable difficulty, accompanied with a serious loss of tin, is sometimes experienced in separating certain metallic and other compounds associated with the tin particle, and having very nearly the same specific gravity, and which compounds, when they occur, must of necessity be removed. Now, they find that by chlorodizing such tin ores (independently of any lixiviation or treatment for other metals) these compounds are decomposed and rendered partly soluble, and so altered in their specific gravity and otherwise as to be readily separated from the tin particle. In case, therefore, of not wishing to put such tin ore through the processes herein named for the recovery of other metals, it may be at once ground to the requisite degreee of fineness in a dry state by rolling, grinding, or other mills, sifted, and washed in their improved buddle until all the lighter and valueless constituents are as far as possible removed. This simple operation brings the ore into the condition technically termed "whits." It may now be dried on the roof of the furnace, mixed with the requisite proportion of salt, and with or without the aid of the hot or cold air blast, roasted until the heavy compounds which interfere with the dressing of the tin are chlorodized or otherwise changed or decomposed, so as to be easily removed by washing, and it is also to be observed that as such ores are generally roasted the addition of the salt which effects so great a change involves very little further expense or trouble, and the chlorodization can be effected with great facility, because not having to fear any volatization or decomposition of silver or copper chloride a high temperature may be employed, but should there be any volatile matters in the ore worth collecting, as arsenic or sulphur, these must be driven off before chlorodizing, and in certain cases, where they are associated with little silver or copper, even before it is finely powdered and washed, as the

roasting will diminish the bulk, aid the pulverization, and clean the tin. On the other hand, if the different bodies alluded to are not present in the ore, and as it is, as not unfrequently, essentially a tin ore, simple grinding and washing in their buddle, without either roasting or chlorodizing, will be sufficient.

In any of these cases, then, when the tin ore has been treated as its variety requires and is ready to be washed, they first place the material in a suitable receptacle where it can be acted upon by water (or it can be placed at once in their buddle if desired), and from which it is washed by a stream into a circular tub thus made: It is in shape somewhat like a brewer's vat, and along the sides, which may be perpendicular or inclined, are placed pieces of wood on hinges, to act as wings or "bafflers," and to turn each way, so as to break up the whirl of the current as required. Within the circle of these wings revolve the spiral blades of a screw fixed in a collar round a frame, and turning with and by a central shaft. These fans wind, so to speak, the lighter particles from the surface of the tin upwards and outwards, and the entire action of the machine is based on the well-known axiom in tin dressing, that the particles of matter acted upon should be forced upwards against the downward current. Below these spiral fans is a double series of lighter fans, which sweep the surface, and tend to distribute the particles of the tin and allow them to settle equally, while below these are four or more strong horizontal bars of iron firmly welded into an iron collar, and having metal teeth riveted into them to act as rakes, the teeth of one rake intersecting with those of the others. These rakes not only help to clear the tin of any impurity, but by their movement and vibration to settle it at the bottom.

As the speed of the shaft and the apparatus attached to the outer frame thereof can be diminished or increased by a strap running over opposite cones of pulleys, as each series of fans can be altered in its position on the shaft, as the whole of the fans and rakes can be raised or lowered together by means of a lever or a weight running over a pulley, as the angle of the spiral blades may be changed at will, and as the angle of the side wings can be also increased or diminished; by all these combined operations any variety of movement may be obtained from the most violent to the most gentle, until the exact degree of motion is found which suits the case. This variety of motion and the washing of the ores are still further aided by upward, and if need be, downward, currents of water from pipes passing the buddle both from the sides and the top. One or more doors are inserted at the side of the buddle near the bottom to remove the washed ore, and a series of openings is made (say) about six inches apart, having projecting mouths capable of being opened or shut at will to allow the washings to escape at different heights, or the water may be made to escape even inch by inch by tin spouts made to fit such projecting mouths, and having different degrees of elevation. When the fans are made to revolve fast or slow, as may be necessary, the heavier particles of tin or other metal fall to the bottom, and the lighter and less valuable matter escapes through any one of the openings at the side as determined on, the movements of the fans being so regulated as to prevent the tin or other valuable matter, while being washed, rising high enough to escape. To avoid any risk, however, from carelessness, the liquid from the buddle may run over a launder having stops, and then if need be over automatic tables, so that nothing worth saving need be lost. Even percussion hammers may be attached to the sides of the buddle, if desired. If stamps are in use the machine will wash the crushed ore and slimes just the same, care being taken that a sufficiency of water is employed; but if stamps alone are used, it is better to crush the ore very coarsely (say, through half-inch grids), and to finish by passing it through a suitable grinding-mill, whereby all the particles are made as uniform as possible.

A SITE has been selected and plan secured for the erection of a free library and museum for Derby. Mr. Bass, M.P., a few years ago gave a donation of £5000 towards the object, and he has now expressed his intention to increase the gift to £8000.

IRRIGATION WORKS IN INDIA, WITH ESPECIAL REFERENCE TO THEIR REMUNERATIVENESS.

By W. T. THORNTON, C. B.

From "Journal of the Society of Arts."

The remunerativeness of Indian irrigation works being the subject of this paper, a very few prefatory remarks will suffice for its introduction.

Every apparatus, from a watering-pot upwards, contrived for conveying water to cultivated land, is entitled to be classed among irrigation works. Such certainly is the *Shadoof*, or pole and bucket, which has been immemorially in use in many Eastern countries, and in India among the rest, for drawing up water from the wells. Such, too, are the wells themselves. In regard to such simple contrivances, however, the question before us does not arise, for they are usually formed by individual cultivators, who would certainly not have gone on making them for so many ages if they had not found their account in so doing. Neither, and for the same reason, does it arise in connection with the tanks or reservoirs, on however large a scale, which village communities or other associations of land owners have, of their own accord, constructed. It is only when the State, or some other second party interposes, and, trusting to its own discretion, provides the means of irrigation, that much doubt can reasonably be entertained, whether the discretion exercised has been a wise one.

Now, in India, the State, not to speak of what was done under native rule, has within the last forty years done a very great deal for irrigation. It has provided one or two districts with tolerably complete systems of tanks, and in most parts of the peninsula has constructed works of a more ambitious character, throwing bunds across rivers high up stream, and from the reservoirs formed behind the bunds, leading off canals, from which, and from whose multitudinous ramifications, water becomes capable of distribution over wide stretches of country lower down, often to the extent of many hundreds of thousands of acres.

Have works of this description hitherto proved, and are they likely hereafter to prove remunerative? This is the question suggested for consideration, and a very important one it is, for on the answer to which it is entitled depends whether or not the State will be warranted in continuing its present course—whether, having laid out between thirteen and fourteen millions sterling on irrigation, it can prudently, in accordance with its present intention, lay out six millions more during the next few years; or whether it had not better stay its hand, and, contenting itself with the liabilities already incurred, not risk any additional funds in the same particular kind of investment.

Before proceeding further, we must, if we desire to proceed safely, settle what precise meaning is to be attached to the word "remunerative."

Every Government that both adequately performs its duties and confines itself within its legitimate functions, is neither more nor less than trustee and administrative agent for the governed. The funds at its disposal are exclusively national money, and whatever investment it makes of this money may, with perfect strictness, be termed remunerative, provided the resulting benefits to the nation at large, of whatever sort the benefits be, are commensurate with the outlay. But, on the other hand, every Government, even the most absolute—even one which theoretically has the entire property of its subjects at its disposal, is practically incapable of appropriating to its own use more than a portion of that property. Practically, its income is limited, and no more than any other recipient of a limited income, can it, without imminent risk of bankruptcy, systematically spend more than its income, borrowing money for the purpose, unless the borrowed money be applied in such a manner as to yield pecuniary returns sufficient to pay the annual interest due to the lenders. Imagine it, for example, to go on raising loan after loan in order to throw down town after town and to rebuild them, in accordance

with the sanitary principles lately enunciated by Dr. Richardson—the good done to the inhabitants of the remodeled towns might possibly be fully equivalent to the money spent, but, unless the inhabitants could be persuaded or compelled to pay rents and rates duly proportioned to the cost of the sanitary improvements, the Government would eventually have no better alternative than that of resolving itself into an insolvent court for self-emancipation from its financial difficulties. Although, then, of the two specified senses of which the the term "remunerative" admits, the first must by no means be disregarded, the second is the one that here claims our chief regard. Be the advantages of irrigation works what they may to the entire community, what more immediately concerns us here is their effect on the Government Treasury; and we may therefore at once proceed to inquire whether those which the British Government has constructed in India do actually make, or are likely to make, within the period during which the Government can afford to wait, satisfactory pecuniary returns upon the capital outlay. Not that we have as yet quite done with our definitions. We have still to determine what species of disbursements ought to be included in, and what excluded from, capital outlay, and also what receipts can properly be treated as irrigation revenue. These points will come before us presently, but for the moment they may be conveniently postponed. Their significance will be better appreciated after a brief examination of such statistical data as are at present accessible.

According to the latest official accounts, the totals of capital which have hitherto been laid out on irrigation works by the British rulers of India are as follows:

	From ordinary income.	From loans.	Total.
Bengal	£93,879	£3,058,019	£3,151,898
North-West Provinces	2,753,530	1,225,634	3,979,164
Punjaub	1,590,058	1,094,221	2,684,279
Madras Presidency	1,015,038	541,488	1,556,526
Bombay Territories, inclusive of Sind	853,165	709,495	1,562,660
Rajpootana	18,943	18,696	37,639
Oudh	44,122	..	44,122
Central Provinces	32,983	..	32,983
British Burmah	211,024	..	211,024

making for the whole of India a total of £13,260,295, whereof £6,612,742 was obtained from ordinary income, and £6,647,553 consists of borrowed money. On a few of the larger complete works the expenditure is stated as follows:

	From income.	From loans.	Total.
Ganges Canal	£2,342,680	£301,945	£2,644,625
Eastern Jumna Canal	201,035	6,708	207,743
Western Jumna Canal	231,389	102,828	334,217
Godavery Delta Works	505,303	138,978	644,281
Kistnah Delta Works	317,053	115,841	432,894
Cauvery Delta Works	1,999	40,205	42,204
Sind Inundation Canals (computed)	483,000	113,000	596,000

Regarding revenue from irrigation works, our statistics are to the following effect: (*See Table on following page.*)

From Oudh and the Central Provinces the returns are *nil*. In Rajpootana there is a loss of £7,156, or nineteen per cent. upon capital, the canals not even paying their working expenses. For all India the net revenue is stated at £1,021,430 or 7.7 per cent.

Among separate works the Ganges Canal is represented as yielding 4.88 per

	Net annual revenue.	Percentage on capital outlay.
North-Western Provinces.	£184,670	.. 4.6
Punjaub	151,826	.. 5.6
Madras....	430,162	.. 27.6
Bombay, including Sind..	264,534	.. 16.9
British Burmah.....	6,917	.. 3.27

cent. The Eastern Jumna, 25.2; the Western Jumna, 30; the Godavery Delta Works, 42.19; the Kistnah Works, 19.73; the Cauvery Works, 273.31; and the Sind Inundation Canals, 33.3.

Before attempting to draw any general deductions from these figures, we shall do well to inquire into their trustworthiness, which, though open to severe criticism in some important particulars, has, I think, been somewhat unduly impugned in regard to others. It must, in the first place, be admitted that the amount given as the total of capital outlay is in part made up of sums which are far from expressing the total cost of the particular works to which they relate. Among the works occupying the highest places in the scale of remunerativeness are several, which, how much so ever they may have been subsequently improved by British engineers, date originally from days long anterior to British domination. The Annicut across the Cauvery, in Tanjore, is supposed to have been raised, and the canals from the reservoir in its rear to have been excavated, by a Hindoo Rajah sixteen centuries before they were remodeled by Sir Arthur Cotton; and the eastern and western Jumna Canals, though re-opened, between 1823 and 1843, by Sir William Baker and his coadjutors, had been first opened more than two hundred years earlier, in the reign of the Mogul sovereign Shah Jehan; while, of the numerous canals branching out from the Indus very many must be nearly as old as the first dawn of civilization in Sind. No one, who reflects for a moment, can suppose that for the £42,000 laid out by the British Government on the Cauvery works, or for the £542,000 expended by it on the Jumna Canals, or for the £600,000 expended on the inundation canals of Sind, the works severally in question could be created, if they had now to be created afresh. Possibly it may be the fact that in Tanjore and Sind the greater part, and it certainly is the fact that in the territories watered by the Jumna Canals, the whole of the present irrigation revenue is due to British expenditure, but it is needless to observe that the percentage of revenue earned in such exceptional circumstances can be no criterion of the percentage of earnings reasonably to be expected from absolutely new works. The admission of such percentage, therefore, into calculations designed to show the average remunerativeness of irrigation works in general cannot fail to mislead, unless very considerable additions be entered on the expenditure side of the account. To judge from the estimated cost per mile of the Soane Canal, £1,200,000 at least must be added for the Jumna Canals, and, from calculations of a different kind, it may be inferred that not less than £250,000 will suffice for the Cauvery, nor than £600,000 for the Sind Canals, so that altogether about £2,050,000 must be added.

The amount given as total capital outlay must further be admitted to be imperfect in not including anything for loss of interest, during construction, on whatever portion of the cost of the several works may have been defrayed with borrowed money. If the works had been paid for entirely by savings from income, such loss of interest would not be properly chargeable against them. It is true, that, if an individual capitalist lay out £100,000 of his own in constructing and fitting up a factory, which is not furnished for a twelvemonth, his money lies unproductive during that period, and the factory may seem to have cost him not merely the amount expended upon it, but also a year's interest thereon at the current rate, and, if that rate be taken at four per cent. to have cost him not £100,000, but £104,000. Here, however, it is assumed that, if his money had not been invested in the factory, it would necessarily have been applied in some other way, which would have yielded him an immediate net return. But this is far from being the case, for the owner of the money might, quite possibly, have engaged in some unlucky mercantile adventure, or might have intrusted his cash to a bubble company, or sunk it in a railway doomed never to make any net earnings, and so, instead of gaining any interest, might have irrevocably lost the principal. Possibly, indeed, he might

have avoided this risk by selecting consols or some other stock adequately guaranteed; but the field offered by such perfect securities is exceedingly small in proportion to the total of capital seeking investment, for the greater part of which there is, therefore, no alternative, besides either letting it lie idle, or committing it to enterprises more or less hazardous. No private person consequently, dealing only with his own money, ever says that he has sunk in a given undertaking more than the principal actually spent. He never, while computing what the undertaking has cost him, dreams of adding interest to principal.

If, however, a private undertaker, having no capital of his own, borrow, at four per cent., £100,000 for expenditure on a factory requiring a twelvemonth for its completion, he will clearly be at the end of the year £104,000 out of pocket; his factory will clearly have lost him so much. Or, if we can suppose a single individual to go on borrowing at the same rate £100,000 a year for ten consecutive years, for expenditure on some work of gigantic proportions, that work will at the end of the ten years have cost its proprietor, not simply the million sterling actually spent upon it, but a million plus the interest he had to pay on his successive loans, or £1,220,000 altogether.

And as of an individual, so of a Government. The Anglo-Indian Government has spent upon irrigation works, which on an average have probably each taken not less than ten years to complete, about £6,650,000, borrowed at four per cent. or thereabouts. To this amount, therefore, should be added £1,463,000 as simple interest during construction. Perhaps it may be thought that the interest reckoned should be not simple but compound, inasmuch as the sums paid annually to the lenders might, if not so payable, have been applied annually to the redemption of previous debts. But although they might have been, they certainly would not have been so applied, but would have been devoted instead to some species of expenditure not directly productive—to the construction of roads perhaps, or of barracks, or of civil buildings; to the extension of education, or possibly to the multiplication of functionaries, or to the augmentation of salaries. Perhaps, too, it may be thought that, not merely should interest on capital during construction be added to cost, but, likewise, all deficits of annual earnings after the works are completed. But why, it may be asked, should this be done in the case of only partially productive expenditure, more than in that of expenditure necessarily and absolutely unproductive? If a palace, when just finished, has cost half-a-million, you would not, ten years later, state its cost at £700,000, because, if the money, instead of being sunk in the palace, had been put out at interest at four per cent., it would, in ten years, have produced so much. Surely, in the case of an unsuccessful irrigation work, as of a palace, the absurdity would be equally great in representing the cost as everlastingly increasing, notwithstanding that all expenditure upon it had long ago ceased. Simple interest on capital during construction, however, is undoubtedly a genuine element of cost, and the addition to be made on this account to the cost of Indian irrigation works, amounts, as we have seen, to nearly a million and a half. Moreover, a third addition, which may be roughly estimated at £400,000, remains to be made for compensation to the owners of land occupied by irrigation works, and for capitalization of the land-tax lost in consequence.

But, if the official accounts underrate in some respects the cost of Indian public works, they somewhat exaggerate it in others. At first sight, it may seem manifest that the pay and allowances for the time being of persons employed in planning, executing, or superintending the execution of any project, are component parts of the outlay on that project; but this is not altogether so manifest as it seems. A very large establishment of engineers, overseers, surveyors, and subordinate employes is permanently entertained in India, at an annual expense to the State of about a million and a half, for the general business of the Public Works Department; and as, if there was no public works to be constructed or maintained, this establishment would not be needed, its entire expense may no doubt, from one point of view, appear justly devisible amongst the whole number of public works. Still it may be

suggested that this establishment may appropriately be likened to a standing army in time of peace. If war break out, whatever extra expenditure is incurred for munitions, stores, commissariat or carriage is, of course, legitimately debited to the war; but, in so far as the troops ordered on active service consist of previously existing regiments, their pay and allowances remain the same as they were in peace, and are never, therefore, reckoned among war charges. It is only the additional forces raised, the entire expense of maintaining and utilizing whom, is so reckoned. In like manner, when any particular Indian public work—the Soane Canal, for example—is undertaken, if for the execution of that work additional engineers or other agents be engaged, the hire of those agents is clearly an essential part of the cost of the particular work. But not so the pay of such of the engineers or others as were already beforehand in the permanent pay of Government. These, if not employed on the Soane Canal, would have been either working, or resting from work, somewhere else—but drawing the regular pay of their rank all the same. To employ these persons on the Soane Canal thus costs the Government nothing, and their pay, consequently, adds nothing to the cost of the canal, and need not, I submit be included in it.

Not only, however, is it included, but to it is added a share of the cost of training engineers and others, and of pensions and of leave allowances of members of the establishment. Now, surely, this addition, at any rate, is unjust, since whether the Soane Canal project had been undertaken or not, the annual expense of Coopers'-hill, or of Roorkee College, would have remained the same, and neither more nor fewer persons have retired on pensions, or have been allowed leave of absence. The charge, too, made for tools and plant seems to me excessive. Even though some articles of this description were purchased with a view exclusively to the requirements of some particular project, it may be doubted whether their entire cost should be added to that of the project, since, after that particular work was completed, they might still be available for other works of the same kind; while, in so far as tools or plant are taken from some pre-existing stock, it seems to me that the project is not justly chargeable with more than their wear and tear.

We come now to irrigation receipts, which in the official accounts are arranged under the two heads of direct and indirect, the former consisting of water rates, tolls on boats, sale proceeds of timber grown on the canal banks, and a few other miscellaneous items—the latter of land revenue assumed to be due to irrigation. As to the direct receipts there is no question; these are, undoubtedly, genuine irrigation earnings, but there is not, nor can there be equal assurance in respect to the indirect receipts. That land, for which irrigation is suitable, is always immensely benefited by irrigation, may indeed be accepted as an ascertained fact, the produce being increased in proportions, varying with the character of the soil, but seldom less than one-half, and sometimes as much as six or sevenfold. The lease-holding middlemen, who intervene between the Government and the cultivating tenants of the soil, observing this increased production, naturally raise their rents, and the Government, when periodically revising its arrangements with the middlemen in those of its territories in which it has not committed the fatal blunder of a permanent settlement, exacts, in its turn, some corresponding addition to its previous share of the rent. Probably, however, it is not to irrigation alone that the growth of the Government revenue from irrigated land is due. Many other causes have most likely co-operated—greater security for life and property, better administration of justice, improved agricultural processes, stricter and more judicious fiscal management; and the members of the public works and revenue departments can never agree as to which of these sets of causes has exerted the most influence, public works' officers naturally laying most stress on the first set, and revenue officers on the second.

This conflict of opinion is especially obstinate and acrimonious in the Madras Presidency, where, as also in the Bombay territories, the actual levy of water-rates is a very exceptional proceeding, and all Government dues, from irrigated and unirrigated land alike, are, as a rule,

collected under the name of land assessment. To get at the exact rights of the matter is of course impossible; some tolerably close approximation to the truth is the utmost that can reasonably be hoped for. As fair a way as any would apparently be to compare fields of similar soil, irrigated and unirrigated, and to credit irrigation with whatever surplus of production was observable in the former. But not to speak of the extreme minuteness of examination which this operation would require, exactly similar soils would seldom be found far apart, and even if found, they would be sure to be differently circumstanced. They could scarcely have equally easy access to good markets, or be farmed with the same skill and judgment, and they would generally be under quite different crops. Practically, then, the controversy is, and needs must be, settled more or less arbitrarily by guesswork, and with such strong prejudices as those under which the guessers are laboring, the sentences passed are sure to be more or less erroneous. Fortunately, however, the errors committed are pretty sure to be on the safe side. In point of fact, it is left to revenue officers to decide what portion of the revenue collections shall be attributed to irrigation; and as these officers are not likely to assign to irrigation more than its due, we may reasonably take for granted that the share assigned to it in the official accounts is rather below than above the mark. We shall not then run much risk of exaggeration in assuming the official figures of revenue to be accurate, so that, after making the necessary corrections in the corresponding figures of expenditure, we may proceed without further delay to compare the two.

To the official total of capital outlay, in round numbers £13,260,000, we must add a million and a-half for loss of interest during construction, £2,050,000, as the difference between what the Anglo-Indian Government has laid out on the Jumna, Cauvery, and Sind Works, and what the entire construction of those works would have cost, and £400,000 as compensation to landowners, and capitalization of land revenue sacrificed; thereby raising the aggregate amount to £17,210,000.

From this amount something ought, perhaps, to be deducted for excess of charge under the heads of establishment, and tools, and plant, but having no means of ascertaining how much should be deducted on this account, I prefer, on the principle of erring on the right side, if at all, to deduct nothing.

There is, however, one and a very important deduction to be made. Of the total of £17,210,000, rather more than three millions have been expended upon surveys and other preparations for schemes not prosecuted beyond the preliminary stage, or upon undertakings which were either abandoned as hopelessly unsuccessful while still unfinished, or which, though expected to turn out well eventually, are as yet only in process of construction, and have not been even partially brought into operation; while half a million more has been absorbed by portions hitherto inoperative of works, other portions of which have been for some time in operation. There are then three millions and a-half which it would be at least premature to admit into calculations designed to show the remunerativeness of irrigational expenditure, and part of which can never with any fairness be so admitted; and by deduction of these three millions and a-half, and of £140,000 for simple interest on three millions, the total of expenditure with which the total revenue is to be contrasted will be brought down to £13,570,000, upon which £1,020,000 is equal to 7.5 per cent., the corresponding provincial percentages, and the percentages of certain specified works being as follows:

	Corrected total of capital.	Percentage of revenue on capital.
North-Western Provinces	£3,565,425	.. £5.2
Punjaub	3,134,702	.. 4.8
Madras	1,893,440	.. 22.72
Bombay, including Sind	2,222,788	.. 11.9
Ganges Canal	2,880,178	.. 4.5
Eastern Jumna Canal	467,978	.. 11.2
Western Jumna Canal	1,306,393	.. 7.6
Godavery Canals	683,705	.. 39.7
Kistnah Canals	467,427	.. 13.2
Cauvery Canals	293,578	.. 36.6
Sind Canals	1,186,000	.. 18.6

Even to myself these are unexpectedly favorable results, and they will probably bly take most other people by surprise, but they will, I hope, be admitted to have been honestly reached. But this is

not all. Pecuniary investments may be remunerative, not only by causing gain, but also by preventing loss; and irrigation is often remarkably efficacious in this second mode. Wherever, in India, agriculture is entirely dependent on the sky for its supply of water, any very sensible failure of the periodical rains is inevitably accompanied by a corresponding failure of the crops, and the Government, besides having to make large remissions of its land assessment, has to incur a large and often immense expenditure in order to prevent the necessarily defaulting cultivators from dying of starvation. Scarcely a year passes without the occurrence of drought in some district or other of the far-stretching peninsula; and there is seldom an interval of more than five or six years without drought spreading over some extensive region. In either case, if means of effective irrigation have been provided in any part of the area affected, their value becomes strikingly apparent. The enormous outlay consequent on the famine of 1874 must have been more enormous still but for the Soane Canal, which even in its then imperfect condition, and when the entire expenditure upon it had not risen above £800,000, enabled luxuriant harvests, valued at £500,000, to come to maturity over 159,000 acres, where otherwise every green leaf must have been parched into powder; and in the rainless autumn of 1860, when other districts in the North-Western Provinces were baked as if in an oven, the Ganges Canal preserved grain crops enough for the sustenance of more than a million of people, who must otherwise have perished, unless kept alive at the expense of the Government, which had already foregone its revenue from the country inhabited by that same million. If the indirect savings annually effected in this way were added to direct annual earnings, the result would be a total that would convince the most sceptical that, regarded as a whole, the investment of the Anglo-Indian Government in irrigation works, has hitherto been decidedly the reverse of unprofitable.

Here, however, it behooves us to be on our guard against the deceptiveness of general conclusions. What practical inference can be drawn from the fact that for all India the average rate of profit on irrigation expenditure is 7.5 per cent., if this imperial average be the medium of provincial averages ranging downwards from twenty-two per cent. to less than nothing, and if of some separate works the percentage is nearly forty? In Sind, where rain so seldom falls that, without artificially conducted water, there would be at best but browsing ground for camels, the canals are for the most part shallow trenches, without headworks of any kind, from fifteen to twenty feet wide, and from five or six to sixty or seventy miles long; but what argument can the financial success of these afford in favor of devoting from three to six millions to the construction of a vast irrigational apparatus in that garden of India, Oudh, which suffers more on the whole from excess than deficiency of water, and where droughts are virtually unknown? or why should it be supposed that, because a system of canals led off from the apex of the delta of a mighty river like the Godavery has answered well, that therefore it would answer equally to throw a bund over the Betwa in Bundelcund, whose bed in a severe drought might quite possibly be left almost as dry as the land on either side. The only useful moral is one which might have been safely assumed beforehand without inquiry into the facts, viz., that there are irrigation works and irrigation works; that when placed in well selected situations, skillfully planned, and economically executed, they will pay well, but that if placed where they are not wanted, or designed upon an extravagant scale, they will pay badly or not at all. No doubt, India offers a wide field for the profitable extension of irrigation, provided operations be carried on with adequate circumspection and forethought; but, no doubt either, that, unless due note be taken of the failures as well as of the successes of the past, failure will continue to preserve the same proportion to success as it has hitherto done.

Passing on now for a moment to a broader view of the general subject, we may be tempted to take for granted that, in so far as the extension of irrigation may prove remunerative to the Government, it must needs prove at least equally beneficial to the nation at large. How can it be otherwise, if its effect will be

to double, treble, perhaps sextuple, the productiveness of the soil, and in equal measure to augment the main constituent of national wealth? If he is proverbially a benefactor of his species who causes two ears of corn to grow where but one grew before, how can corresponding praise be denied to a process that causes land to produce sustenance sufficient for double or treble its previous population? At the risk of being charged with paradox, I must hint a doubt as to the apparent truism to which these questions point. The mere quantity of national wealth is sometimes of less importance than its distribution. Wherever, as in a portion of the Damoodah Valley described by Colonel Haig, the present Chief Engineer in Lower Bengal, there is an agrarian population of little less than a thousand to the square mile, belonging mainly to the ryot class, and with, on an average, not more than a pound of rice per head per day to live upon, matters would, I imagine, not be greatly mended by arrangements which caused two thousand per mile of such wretched starvelings to take their place, even though at the same time the incomes of the half-dozen zemindars interspersed amongst them should be quadrupled or quintupled. This latter augmentation of the possibilities of human happiness would not go far towards counterbalancing the unequivocal multiplication of human misery. Now this, or something like this, is often the principal change to be expected from irrigation, operating by itself, and unaccompanied by subsidiary influences. In the greater part of Northern, in great part of Central, and in considerable portions of Southern India, the bulk of the peasantry are a cottier tenantry, who often legally and almost always practically, are liable to have their rents raised at the discretion of the zemindars or of the middlemen, of whom they hold. As a natural consequence, wherever irrigation is introduced, rents are raised. If any general inference may be drawn from Colonel Haig's observation of what has already taken place in Orissa, they are almost immediately doubled, trebled, or quadrupled, according to the character of the soil. The Government and the zemindars or the long leaseholders, between whom the proprietorship of the land is permanently or temporarily divided, divide also the profits of irrigation, while the ryots—the immediate occupants and tillers of the ground—share only infinitessimally, if at all. Bearing these facts in mind, not only am I not prepared to admit that the application to irrigation of immense sums of public money must necessarily be for the benefit of the community regarded as a whole, where a large majority of the population consists of ryots—I cannot, also, but think it exceedingly hard that, in so far as the money is raised at the expense of the ryots, it should be devoted to works, one principal effect of which is to subject the ryots to increased exactions. I cannot bring myself to set much store by irrigation unless it be accompanied by such modifications of the present system of land tenure, as, by securing to the actual cultivator a sufficiently augmented share in the fruits of his industry, may be calculated to raise his standard of comfort, and so to hold out a prospect of a lasting improvement in his material condition. Here, however, I am adverting to a subject but slightly connected with the one immediately before us, and which I will not venture to pursue further. Indeed, all that I should have liked to say upon it, if opportunity had served, has been already said in a special chapter of a recent volume of mine on "Indian Public Works."

One other point demands a few words of notice before this paper is brought to a close. It will, I trust, have been observed, that I have anxiously endeavored to do the best with my materials, dealing with them quite impartially, and neither aught extenuating nor aught setting down in malice. Yet I cannot but feel that the conclusions arrived at are, after all, but dubious approximations to the truth, and I am bound to confess that I have been compelled to resort largely to conjecture, in order to fill up gaps in the statistical records. These, consisting of Finance and Reports of Public Works, Administration Reports, Irrigation Revenue Reports, Board of Revenue Reports, Forecasts of Expenditure, Government Resolutions, and Miscellaneous Minutes and Memoranda, are voluminous enough in all conscience, but that is about the highest praise that can fairly be claimed for them. No one that

I know of has them more completely at his fingers' ends than my friend, Mr. Frederick Danvers, to whom I am exceedingly indebted for his valuable aid in analysing their contents, and he, I am sure, will bear me out in saying that, if their object had been the mystification instead of the enlightenment of the reader, they could scarcely have been more cleverly contrived for that sinister purpose. Their internal arrangement has indeed been carefully—even painfully—elaborated ; exhibiting a straining after almost metaphysical refinements. The figures are distributed into divisions and sub-divisions, classes and sub-classes, heads, sub-heads, and sub-sub-heads, but when we proceed to inquire what are the subjects of this beautiful capitular gradnation, we are sadly tantalized at finding how little solid grain can be extracted from the imposing array of fair-seeming husks. Scarcely any two documents have been drawn up on the same plan, and even in one and the same document there are sometimes discrepancies not easily reconcilable. Thus, according to one set of accounts the total of irrigation revenue for all India is £1,020,000, whereof Madras is credited with £430,000. In a separate table, purporting to exhibit the entire irrigation revenue brought to account in the Public Works Department, the total is reduced to £475,000, towards which Madras contributes something less than £7,000, the column for water-rates being left blank in the place opposite Madras. Yet in a third document £220,000 of water-rates are assigned to Madras, while a fourth informs us that in Madras water-rates are, as a rule, not collected at all. Again, the irrigation revenue of the Bombay territories for 1873-4, is in one set of papers stated at £260,000, and in another at £100,000 more, and it is only by referring to entirely separate documentary evidence, that we find that, whereas the smaller sum represents net revenue, the larger represents gross receipts previously to the deduction of working and maintenance expenses.

Plainly these things ought not so to be, and it is but fair to mention that the Indian Government does not intend that they shall so remain ; though I must take the liberty of questioning whether it is going the best way to work to set them to rights. What has hitherto most attracted attention is the defectiveness of the revenue accounts ; and in these, no doubt, there is much room for amendment. However impossible it may be to discover any principle, whereby the proportion of land reveuue due to irrigation can be determined with perfect accuracy, and however indispensable, consequently, to select some mode more or less arbitrary, one and the same mode ought at all events to be adopted throughout India. There should not be one measure of apportionment for Bengal, the North-West, and the Punjaub, another for Madras, and yet another for Bombay. The selfsame items, too, should everywhere be deducted from gross receipts in order to produce a net residuum.

But the craving for uniformity and symmetry prevailing just now in the Accounts Branch of the Public Works Department, is not to be appeased by such concessions, and an edict has gone forth that the form in which Public Works books are kept in Bengal and its sister provinces, shall in future be taken as a pattern in the rest of India. Now in the Bengal books, actually realized water-rates figure largely among the receipts, whereas in the Madras and Bombay Presidencies water-rates are at most levied only exceptionally, and there is strong reason for doubting whether they are levied at all. The descriptions given of the existing practice are provokingly ambiguous, but as far as can be made out, what really takes place is this. The whole of the ryot's dues, in respect of irrigated as of unirrigated land, is paid by him in a lump sum under the name of land assessment ; but in some districts the total amount paid is subsequently divided by the revenue officers into water-tax and land-tax, and entered in their books accordingly. But whether water-rates have any real existence or not, it has been ordained that they shall henceforth appear in the Madras and Bombay books, just as they do in those of Bengal, and there are two ways in which the order may be complied with. Either the farce of entering under one name what has been received under another, may be enforced universally, or two distinct demands instead of one may really be made upon the ryot, whom, how-

ever, it may then be difficult to persuade that his aggregate taxation has not been added to, instead of being simply divided. In either case, much additional trouble must be taken, much time wasted, and much additional expense incurred, and, in one of the cases, a very mischievous impression produced into the bargain.

And all for what purpose? The real desideratum is to ascertain the total net return yielded by irrigation, but nothing will be gained by decomposing the total, and assigning separate names to its several component parts. If so much more be styled water-rate, so much less must be styled land-tax; in all else things will remain as they were. But with a tithe of the time and trouble requisite for this unnecessary change, some substantial improvements might be effected in the expenditure side of the accounts.

Mr. Danvers and I have endeavoured to correct the official estimate of capital outlay by computing, as well as we could with the data in our possession, how much should be added for original cost of ancient works, for interest during construction, for compensation for land occupied, and for capitalisation of land revenue lost, and also how much should be deducted on account of expeditnre which it would have been unfair or premature to include in our calculations; but what we, here in England, could do only with doubt and hesitation, might be done in India with comparative confidence. Where we have to often been obliged to guess, inquirers on the spot, with local experience, technical knowledge, and free access to details, might decide authoritatively, and produce in consequence an irrigational balance-sheet little in need of the apologies for possible, or rather inevitable inaccuracies with which the present paper must necessarily conclude.

THE BLACK SEA AND THE CASPIAN.

From "Engineering."

THE following paper by Mr. Henry C. Spalding, an American engineer who has lately been visiting Europe, will be read with much interest. Mr. Spalding has been good enough to promise us further details of his plans, and these details we hope before long to lay before our readers, when we shall have something to say on the general bearings of this grand and highly interesting scheme. Meanwhile we may state that the paper we subjoin is now in course of translation and publication into the Russian language by Colonel Muller, of the Russian War Minister's staff, and it has been submitted to his Excellency Peter Semenoff, President of the Imperial Geographical and Statistical Commission.

"In the southern portion of the Russian Empire, along the border lands which separate Europe from Asia, there is situated a great basin, depressed below the level of the ocean. This basin receives into the sea which occupies its lowermost parts, besides smaller tributaries, the two great rivers Ural and Volga, which drain a very large proportion of the central regions of the empire.

"These tributaries having for a very great length of time, by the processes of detrition and alluvion, deposited the soil of the extensive districts drained by them in this sea, its dimensions have become contracted, and the bottom of the remaining portions elevated, until very large areas are becoming unnavigable, and until, by reason of the diminution of the water spaces available for evaporation, the surrounding regions are becoming sterile wastes, and the commerce which should enliven both sea and land, diminishes, notwithstanding the approach of civilization. These processes, slowly but surely and steadily advancing onwards, will in time convert this sea into a great marsh, and lands still productive into barren and desert regions. The results of the gradual shoaling of this sea, and of the contraction of the area of its waters, so far as navigation is concerned, are easily foreseen. But of the climatic change and its results—the more impor-

tant subject—less is generally known and appreciated. Therefore a few words upon that topic may be pardoned.

"It is well known that vegetation depends for nourishment and sustenance, first upon the air, and secondly upon moisture. The air supplies the carbon to the growing plant through its foliage, and it is carbon which, by its combustion, produces heat, whether in the fire or in the animal economy. But without moisture the carbon of the atmosphere could not be received into the leaves, nor could it be distributed from them through the branches or stem. Without moisture the salts and the silex of the earth, necessary to give strength to the plant, could not be dissolved and supplied to the roots, nor could they be received by the roots and distributed throughout the plant without the aid of moisture. Therefore, as the value of any region for the habitation and support of man or beast is dependent upon water, the effect of diminishing the water area of the interior of great continents is to bring about barrenness and depopulation in proportion to the extent of this diminution, just as surely as the absence of the sun brings about darkness. The first effect of the shrinkage or contraction of the area of the Caspian Sea was to diminish the fertility of the districts immediately adjoining it, except to the westward, but a secondary result was that as their water supply diminished the evil spread and increased, because evaporation proceeds upon land also when there is any appreciable supply of moisture; so that by the loss of the equilibrium between demand and supply this evil influence has already, by its reflex action, distributed itself over a great region in Asia as well as over a lesser area in Europe, while there is a prospect of a further and steady increase of its effects.

"These influences, both direct and reflex, have also been exerted in the cases of Lake Balkash and the Aral Sea; direct in the matter of detrition and alluvion caused by their own river systems, reflex in the hastening of their shallowing and loss of evaporation area, because of the shrunken proportions of the Caspian.

"Therefore, through the operation of these natural laws a great desert is in process of formation in the midst of the Russian Empire.

"The questions how this disaster may be averted for some thousands of years, and how, by a counteraction, and, to some extent, a reversal of these processes, great advantages, commercial, industrial, political, and social, may be secured to this region and to the empire, will form the subject of this paper.

The process of deterioration already described was probably the occasion which drove forth the vast multitudes in ancient times from the then unknown East to Europe, whose migrations, battles, and conquests are mentioned by the Greek and Roman historians of the period. The regions of their birth being no longer able to support them, these people were forced to seek others more inviting; and thus by long journeyings and through many wars, they occupied the whole of Europe, which, with its more fertile soil and less warlike population, invited both conquest and occupation.

"When we look at the geographical situation in the light of ancient history we see that it is almost impossible that any other region than the one under consideration could have furnished conquerors and colonisers to Europe within such a limited time, because upon no lesser portion of Asia could such a great number of people have subsisted. This is evident when we consider that nearly all the region to the south of the Aral and the Caspian was known to the ancients, to such an extent, at least, that the people could be identified and the places whence they came located, and their line of migration thence would naturally have been into Asia Minor, and not to the north of the Black Sea. Some of them may have come from the far north in Siberia, but of the large number of great tribes whose descendants now inhabit Europe by far the larger part must have come from the regions in the vicinity of the Aral and Caspian Seas. The Russian Empire may, therefore, justly claim to have been the birthplace of all the nations of Europe. The reversal of the processes of deterioration and depopulation, and the renewal of the favorable conditions under which those regions became the cradle of the human race, are matters of much importance from every

point of view, and supply themes well worthy of discussion.

"While there may be imperfections detected in this paper in the estimates based upon rough calculations, the points presented and theories advanced will probably be found stated with sufficient precision for the purposes of a general review of the subject.

"In considering the sources whence the requisite supply of water may be drawn for this purpose, we are brought to two conclusions—first, that the supply should be ample and unfailing; secondly, that the works by which this supply is secured should be fully equal to any demand for maritime purposes. These requisites are only to be found in the direction of the Black Sea. This sea, by means of its connection with the Mediterranean, can furnish both the water supply and the maritime facilities for commercial and naval communication with all the world. By means of a cutting, about 250 versts in length, across the ridge dividing the two seas, connecting them upon one level, these results can be obtained with certainty.

"This cutting should be, when completed, an artificial strait, deep enough for ships of any draught, and wide enough for ships of any width to pass each other. Here, of course, the usual objection arises that the cost of such a work would be so great that it can never be executed, nor made profitable when completed. Neither of these objections is tenable, if the best method of accomplishing the work is employed, and if the questions of loss or gain are fully considered.

"The way to construct such a work presents itself first in order, and it will be shown that this is easier than has hitherto been supposed.

"Beginning in the basin of the Caspian Sea, at a point fifteen meters below the level of the Black Sea, a level cutting 150 meters wide should be made westward, to such a distance that at its western extremity it would reach a depth of ten meters. The surface of the earth at that point would be five meters below the level of the Black Sea. Here this broad and deep cutting should be discontinued, and a narrower and shallower cutting should begin, which, with certain exceptions, should be carried all the way across. The broad and deep excavation would be short, and the expense of it inconsiderable; yet, by its formation, it would, in the end, govern the character of the whole work.

"If, between this and the waters of the Black Sea, a cutting only five meters below the sea level at one end and three at the other, fifty meters in width, were to be made the water would flow through it at a speed of about twelve kilometers per hour, and, upon reaching the end, would be precipitated down a fall of ten meters in height into a basin thrice as broad as the channel whence they fell, and from which an easy exit could be made into the Caspian Sea. The effect of this outfall into earth of ordinary consistency would be to give it a tremendous excavating power. The force of the water, acquired by this plunge, would be exerted in excavation in four directions—first, in deepening the waterway at the foot of the fall; secondly, in cutting away the earth around the three sides of the basin; while the fact of its nearness to a still greater outfall would give it such rapidity of current in the lower channel that for a long time it would carry with it into the sea all the materials thus excavated.

"It will be perceived that the element of reduction of cost of the work is found in the utilization of water for the purposes of excavation. This powerful excavator is known to be able to perform its work with great rapidity and little expense, and it may safely be trusted to excavate a large channel through all loose or soft earths, from the Black Sea to the Caspian, not less than fifteen meters deep nor less than 150 meters wide. In order, however, that these dimensions should be obtained, it will be necessary to cut through all ledges of rocks or strata of indurated earth to the full depth and width. These can be located by boring, and examined by pits, after which they may be removed by the usual processes of excavation before the water is let in to perform its work.

"The movement of the water through a channel of three meters by fifty meters, at a rate of twelve kilometers per hour, would fill a space in a year equal to 522 square kilometers from the level of the Caspian to that of the Black Sea. This would fill the present area of the Caspian to the

level of the Black Sea in about 700 years; but, as it would be enlarged by the process from about 493,000 square kilometers to about 700,000 square kilometers, the filling would go on very slowly until the channel of the new strait should have become enlarged to its full dimensions. This enlargement would proceed at the rate of about one verst per week, and, as the entire distance to be enlarged would probably not exceed 300 versts, it would be completed in about six years, after which the filling would proceed with a current of about twenty kilometers per hour, so that, at the end of forty years from the beginning of the work, the levels of the two seas would be so nearly uniform that navigation of the new channel could begin. This time could be shortened to about twenty-five years, if, upon the completion of the work already described, a sufficient quantity of the plant employed in that operation were to be used in repeating it, by connecting the rivers Don and Volga. The work there, being shorter, would be completed with great rapidity, and a cutting sufficient to let the waters of the Don flow through in the manner already described could be excavated and enlarged by the water at about the same time as that from the Black Sea.

"The cut from the Don could be cheapened and expedited by the construction of a dam just below the cut, which would temporarily set its waters at a higher level. In this way the excavation of a less amount of earth by steam would be necessary, and the increased fall of water would enlarge this channel to dimensions as great as the other. As soon as the waters of the Don had cut a passage to the Volga sufficiently below its natural bed, the dam could be removed, when, if the old bed of the river between this point and the Sea of Azof were low enough to allow it, the waters of this sea would swell the volume discharging into the Caspian by the simple process of reversing the current of the river between those points. A similar work was performed in America by cutting through the ridge of limestone which separated the waters of the Chicago River from those of the Illinois River. The result was that the current of the Chicago was reversed, and it now discharges its waters, as well as those of Lake Michigan, into the Illinois, and through that, *via* the Mississippi River, into the Gulf of Mexico, instead of the Gulf of St. Lawrence. If it were possible thus temporarily to reverse the current of the Don, the effect would probably be to deepen its channel and render it navigable for large steamships. The temporary inconvenience caused by such an operation would then be repaid by increasing the usefulness of that river, and by making it also a part of the new field of commercial and industrial operations. The labor of cutting these two water ways should be performed by steam, and the plant used for the first could afterwards be employed upon the second. With a sufficient equipment, the entire work upon both should be completed in six years. The expense upon the above plan for making the excavations necessary for replenishing these great interior basins would not exceed one-third of the cost which would be incurred in constructing these works by the usual method, so that the outlay would be brought within reasonable limits. The material excavated near the Black Sea should be deposited in the sea in embankments. Each of these lines of embankment should extend into deep water, where they should converge until the opening between them would be 500 meters. As material would be abundant, the embankments may be broad, thus insuring permanence, and the interior space would form a safe and capacious harbor.

"At the Caspian end these embankments should also be formed, but they should be placed in such a position that the earth washed out from the excavation should not enter the enclosed space. This would necessitate placing this harbor upon one side of the canal and the entire separation of it until the channel became navigable, after which the water could be made to flow through it, and the opening of the new strait into the sea could be closed.

"In the construction of the interior harbor it might be lined with quays. The facilities for doing this would be very considerable, because there would be no water in it until it was filled from the Black Sea; therefore the expense would be much less than that which attends the construction of quays under

the usual circumstances. This harbor should be the commercial seaport of the whole of the interior basins, and round it would grow up a large city.

"It may be objected to this plan that the alluvion deposited in the Caspian would tend towards filling it with solid matter, and so accelerate the progress of the evil influence of its natural tributaries. This objection, though well founded, is trival. The amount of solid substances brought in during the period of filling would be less than that deposited by the rivers during the same period. Therefore its effect upon so great a body of water would not be perceptible unless it were carefully looked for; and as the economy of the process is so great we can well afford to shorten a little the interval of thousands of years which must elapse before its dimensions will again be reduced to their present area.

"The surplus material removed after the formation of the harbors should be formed into a series of great fortifications. The country on either side of this channel could thus be made impregnable to attack upon land, and the strait itself would be more strongly fortified than any water passage in the world. As this great basin would be rendered secure from hostile approach by sea, it would be the best place in the whole world to establish dockyards, armories, and arsenals for building and repairing ships, and preparing and storing arms and ammunition.

"This new Mediterranean would be navigable for large ships from the borders of Persia to about the fiftieth parallel of north latitude along the estuaries formed by the Ural and the Volga, and it would be navigable for smaller seagoing ships to Orenburg, on the Ural, and a point still further north in the Volga. The access thus given to the forests of Eastern Russia and of Siberia would soon show its results in the establishment of shipbuilding there upon a large scale. The ability to furnish cheap transportation for the coal of Southern Russia to the Ural and the Volga, where it would meet the iron ores of the Ural Mountains, would lead to the establishment at these heads of navigation of great industries in the production and manufacture of iron, while the facility afforded by the returning colliers for shipping these ores to the Black Sea ports would soon show results in the establishment of kindred industries there also. By the construction of lines of railway from the central portions of Western Siberia to Orenburg, the shipment of grain and other heavy agricultural productions of that region would greatly increase, because these require the cheaper water transportation to stimulate increased production. By railways from Turkestan and Western China to the river Emba, a port in the valley of that now useless stream would soon come into existence, where the wool, cotton, tea, and other productions of those countries would be exchanged with the Mediterranean for the fruits, wines, and manufactures of that region. The productions of Persia and her imports also would be sent to the harbor formed by the Atreck river, instead of going to the Indian Ocean and the Persian Gulf. And thus this new Mediterranean would rival in importance the well-known sea of ancient and modern times. So far as Russia is concerned, she could realize, on this new navigation, the boast of the French regarding the older one, who said they would made the Mediterranean a French lake. The new Mediterranean could be made a Russian lake. By the adoption of a similar rule to that applied by the United States, all foreign vessels would be excluded from these waters. The result would be that among the fishermen and nomads of those districts would grow up a race of sailors to navigate the great commercial fleets which would soon exist there; and, besides this, it would be the training school for sailors for a navy.

"The addition of nearly one-half to the present area of the Caspian would at once increase the rainfall of those districts in the same proportion, and the result of evaporation upon land would soon enlarge the extent and increase the quantity of rainfall by the reversal of the process already described. As this continued, one of the first effects would be to dissolve and wash out the salts of the steppes, which would promote their fertility and soon render them valuable for pasturage. A little more remote, but none the less important, would be the effect of increased rainfall upon the slopes drained into the Aral Sea and

Lake Balkash. By this indirect process of supply, the beneficial influences of the new strait would soon begin to exert themselves—first, in promoting fertility and preventing barrenness; secondly, in mitigating the severity of the winters over a very great region, and in preventing great changes of temperature in the vicinity of these bodies of water; thirdly, in so deepening and enlarging the water areas of these shrunken and shrinking lakes as to give better and larger opportunities for navigation, so that these vast regions, now relasping into desert wastes, would be restored to what was probable their primeval condition, as the abodes of countless millions of men and beasts and the habitations of plenty and prosperity.

"To realize that this is not a mere high flight of imagination, it is only necessary to contrast this region and its great empty reservoirs with that of the coresponding latitudes in the heart of the American Continent. With about equal reservoir capacity, the region surrounding the great lakes is one of the most genial and fertile on the globe. Were its reservoirs as empty as these in Asia it would be equally as barren and unproductive. These great reservoir spaces present many other analogies to those of the American Continent, both in respect to area and to the facilities for extensive commercial operations, and their filling would in time bring about results equally important in the population and the wealth of the surrounding districts as those which have been compassed in America in a very limited period by the contact of civilization with the shores of the great lakes.

"Such a great triumph of a nation over Nature would be by far the greatest conquest in the annals of human material progress, and the monarch who should achieve it would live in the memory of mankind longer than any other recorded in history. And, although the fruits of success might not be enjoyed by the present generation, the great empire which should reap and inherit the accumulated result will be the more powerful and healthy through it and the more firmly established and knit together by it than it could be by any other means, and of that empire it would be the most crowning glory and achievement."

IRON TRADE PROSPECTS.

From "The Engineer."

It is probable that the iron trade of Great Britain was never before in so deplorable a condition as at present. It is true that prices have ruled a little lower than they do at this moment, and that orders were fewer and smaller; but the amount of depreciation which a trade undergoes cannot be measured by prices or orders alone. A paucity of orders and minimum prices may be matters of little moment if the capital and plant which are rendered inoperative are small and cheap. The present position of our iron trade cannot be viewed without apprehension, simply because the capital invested in iron and coal mines, blast furnaces, and rolling mill machinery is enormous. The failure of the iron trade of this country is a national calamity. It is not an affair of a few hundreds of thousands of pounds, for the questions involved affect nearly every member of the community. At no time in the history of England had the iron trade assumed such enormous proportions as those which it reached about two years ago. The sums invested in it must be measured by millions of pounds sterling; while the number of individuals who obtained a living, directly, or indirectly, by the manufacture and sale of iron, was greater than at any previous period. Consequently the cessation in the demand for iron exerts an influence for evil which does not admit of comparison with previous disasters. Indeed, it is not perhaps too much to say, that the demand for iron which exists at this moment would, some twenty years ago, have been sufficient to keep most of the blast furnaces, mills, and forges then in existence fairly employed. The present collapse is disastrous, because the means

of production rendered valueless are so great, and the number of hands thrown out of work is so large.

It is easy to find reasons for the existing deplorable condition of the iron trade; it is not very easy, however, to find reasons which shall be deemed conclusive. In point of fact, there can be no doubt that we must seek for the origin of the evil, not in one source but in many. It would be impossible to consider the whole subject, complex as it is, within the limits at our disposal; nor are we certain that a complete enunciation of the truth would be productive of any good. But there is, after all, a certain melancholy pleasure in knowing the source of our troubles, even though the misfortune does not admit of being combatted; and we think an explanation of one or two of the principal reasons why iron is at present so cheap may interest our readers. It is as a matter of course understood that iron is cheap because there is little or no demand for it. We cannot stop here, however, because all questions connected with the iron trade narrow themselves into one—why is the demand for iron so small? An obvious reply to this question suggests itself in a moment. There is no demand for iron because there is no speculation. With nearly 100 millions of gold locked up in the Banks of Englands and France, while war clouds gather gloomily over the Eastern horizon, speculation is dead. It may be proved that for many years past it has been practically impossible to invest any considerable sum of money in a renumerative way without the aid of the engineer. Railways, mines, steamships, docks, factories, roads, all things from which a profit is to be derived have their origin, it may be, in the minds of the capitalist and the speculator, but they owe their practical existence to the abilities of the members of our profession. But just now there is no work for engineers, and it must, we think, be added that engineers have not recently suggested any sound speculations in which capital might be safely and profitably invested. There is plenty of work to be done both at home and abroad, but it is not done, and neither engineer nor capitalist suggest that it should be done. Here, then, is one potent reason why the demand for iron is small; but this is not the sole reason. Foreign competition has come into operation. The fact is fully recognized, but the precise meaning of the term is hardly as well understood as it might be. Ironmasters in this country are inclined to regard the dealings of their brethren in Belgium or the United States too much in a personal light. They are disposed to take umbrage at the efforts of men who are really in not a whit better plight than we are. It is not the iron trade of England alone, but the iron trade of the whole world that is in a depressed condition. The supply of iron is greater than the demand; and it does not appear that any great benefit could accrue at the present moment from the discovery of a system of making iron by which the cost of production could be lessened, unless the operation of that method could be limited to a given district or country, which would then be in a position to undersell its fellows. If bar iron could be made and sold to morrow for £5 a ton in England and on the Continent, the iron trade would no doubt receive an impetus which would for the moment prove useful; but in the end—and the end would be quickly reached—we should be no better off than we are at present. The uses of iron are, after all, comparatively limited; and although it is true that if iron could be had at a very low price it would be used as a substitute for wood and stone as it is not used now, it must be borne in mind that, on the other hand, the moment it became apparent that a profit might be made out of iron, new works would be put down, and the production of the metal would be enormously increased. The prime truth is that if iron is to be dear it must be scarce; and even though the metal could be made for a few shillings a ton, the position of the trade would not be improved. On the contrary, it is well known that when wages are highest and coal dearest the greatest profit is realized by the ironmaster, provided the value of iron rises in the same way. In other words, a man will make a larger profit out of 1000 tons of iron sold at £10 a ton than he will out of 2000 tons of iron sold at £7 a ton. We confess, therefore, that we see little reason to believe that new methods of making iron can materially improve the prospects of

the ironmaster. Englishmen cannot hope to keep the best modes of manufacture to themselves; and although they cannot afford to permit Belgium or America to beat them in the race for cheap iron, it does not follow that, having got cheap iron, they will be better off than they were before. It is true that the world at large will possible be the better of a reduction in the cost of production, but even this is open to question. We are not, however, dealing with the world at large, but with the iron trade of Great Britain alone.

The future prosperity of the iron trade, then, depends not on producing cheaper and cheaper iron, but on the demand which may exist for the metal. If iron is really wanted it will be purchased at any price in reason. We cannot call to mind an instance in which speculation has been stopped because iron was dear. Who ever heard of a railway scheme being abandoned because rails rose a pound a ton in price? It is almost impossible to arrive at any trustworthy statistics on the subject, but we think it will be found that even a considerable fall in quotations for iron exerts but a small influence on the quantity of iron actually sold. This statement may be misconstrued, therefore we shall put it in another form, namely, that the whole quantity of iron sold during a year in England is little affected by the price at which it is sold. If this be true, then the idea that if iron could be made more cheaply than at present more of it could be sold with profit is a delusion. It would not be a delusion if, as we have explained, the production of cheap iron could be confined to a single country—at least for that country; but such a condition in the present day is impossible, and there is no hope for the iron trade of the future save in augmented demand.

The demand for iron is two-fold in character. It originates, firstly, in the requirements for new undertakings, and secondly, in the need for repairs. Until some confidence is restored, and money is once more available for the construction of engineering works, there will be no demand under the first head. As regards the second, there is reason to believe that the demand will become proportionately smaller every year—not absolutely smaller, but less in a sense which is well illustrated by the iron trade. At one period this trade was well supported, even in so-called bad times, by the needs of the railway companies. Iron rails wore out quickly, and had to be replaced; but steel rails are sold now at little more than the price of iron rails, and they last two or three times as long. It is not remarkable that under these conditions the rail trade should be bad; the introduction of cheap and good steel rails killed a goose which laid golden eggs. We do not say that it was not for the good of the nation at large that the goose was killed, but it is none the less certain that her death has been a heavy loss to the iron trade of the country. The truth is, that better iron is now made than it was the general custom to make heretofore, and this iron is used to more advantage not only on railways, but in ships, and buildings, and the hundred-and-one purposes to which the metal is put, and the result is that the demand for iron for repairs is reduced. There is no remedy for this condition of affairs, but ironmasters may rest assured that the worst enemy with which they have to fight is steel. If this metal ever takes the place now held by iron, the pig-iron trade of the world will apparently undergo an immense reduction in its dimensions.

A NOTE relative to the influence of living vegetable roots on putrefaction has been communicated by Dr. Jeannel to a recent number of the *Annales de Chimie*. He says that the project of utilizing the sewage waters of Paris by irrigating the surrounding lands gave rise to hygienic apprehension; this problem seems to have been satisfactorily solved by the fact that the farmers living on the soil are not subject to maladies caused by the decomposition of animal matter; from a series of scientific experiments, the author concludes that the roots of plants in vegetation have the effect of arresting the putrefaction of organic matters held in suspension in water; besides acting as sources of oxygen, under their influence ferments and animalcules of putrefaction disappear and are replaced by those living in water comparatively salubrious.

PERMANENT WAY OF RAILWAYS.*

By Mr. R. PRICE WILLIAMS, C. E.

From "Engineering."

When, ten years since, the subject of the maintenance and renewals of permanent way was discussed at the Institution, steel rails might be said to have been on their trial. In the few instances where they had been used, they were laid rather as an experiment at stations, and in situations where, from the slow speed of the traffic, no risk was incurred of those sudden fractures to which, it was feared, their brittle character rendered them peculiarly liable. Experience had, however, shown that these fears were groundless, and that steel, with the small percentage of carbon used for rails, was a material greatly superior to iron, both in strength and durability, and not more liable to sudden fracture. Steel rails had now almost entirely superseded iron rails on the main lines in this country, and the recent reduction in cost of manufacture would probably lead to steel being used exclusively for rails.

In 1865, the author showed that the average life of iron rails under heavy traffic was then only three years. Since that time, the goods and mineral traffic on some of the principal English railways had been doubled, and even trebled. As might be expected, this had led to increased expenditure in the maintenance and renewals of the permanent way, but in nothing like the same proportion—a fact testifying to the more durable quality of the materials. Thus in the last ten years on the Great Northern Railway the tonnage had increased 177 per cent., while the cost per mile of maintenance had only risen forty-five per cent.; on the Midland the tonnage had increased 113 per cent., and the cost of maintenance sixty-four per cent., the chief portion of this latter increase being for materials. On the South-Eastern and the London and Brighton lines, the relatively small increase in the course of labor per mile was observable, but there had been a considerable increase in the cost of staff and office charges.

In 1868, the half-yearly reports of the railway companies were required to be prepared according to a uniform system. The distinction between the maintenance and renewals was then abolished. The cost of maintaining the sidings, points, and crossings, hitherto included in the "station works," was charged against "maintenance of way." The author had arranged the tables and diagrams in accordance with this new system. In comparing the cost of maintenance on different railways, it was necessary to take into account the gradients, weight, and speed of traffic in each case, as also the relative mileage of single, double, and triple lines, length of sidings, &c. To afford a common basis of comparison, the author had given the cost of maintenance both per mile of railway and per mile of single line; and much more uniformity was found in the latter than in the former.

The average cost of the maintenance and renewals of the permanent way on the Great Northern Railway, during the year 1865, was £124 per mile of single line, the net cost of relaying a mile of single line with iron rails being £1371 Dividing the latter amount by 124, gave eleven years as the average "money life" at that time; in other words, the annual sum then spent would renew the entire mileage of the railway in that period. In 1875, when steel rails were used, the cost of maintenance and renewals per mile of single line was £184.78, the net cost of relaying a mile of single line being £1626, giving a "money life" of only nine years. The "money life" of this permanent way had therefore diminished during the last ten years, a result due partly to the rise in wages, but chiefly to the increased amount of labor in upholding the substructure of the road; indeed, the cost of labor in "maintenance" amounted to four times the labor required for "renewals." On comparing the average cost of the maintenance and renewals of the nine principal English railways, it appeared that on the Lancashire and Yorkshire Railway it was the highest, and that consequently the

* A paper read before the Institution of Civil Engineers.

"money life" was the least, viz., only 6.66 years; the maximum "money life" being found on the South Eastern and the London and Brighton Railways, viz., 10.50 and 10.38 years respectively. The average annual cost per mile of single line of the nine railways alluded to during the last ten years, was about £158 per annum, equivalent to an average "money life" of 7.61 years, assuming iron rails to have been used for the renewals. During 1875, the average cost of maintenance of these nine railways had been £213.64 per mile of single line, which, even assuming, as was not the case, that steel rails had been entirely used for renewals, gave only 7¾ years as the present "money life" of nearly one-half the railway mileage of the kingdom. The annual cost of the maintenance of the permanent way on these railways represented 2.10 per cent. interest on the ordinary capital, so that one year's increased "money life" would be equivalent to an addition of ¼ per cent. interest on such capital—a fact which showed the importance of the efforts to render the permanent way more durable.

The actual life, or duration, of the permanent way should not be confounded with the "money life," the latter being merely the ratio which the annual cost of maintenance bore to the cost of construction. In the author's previous paper, it was mentioned that some iron rails on a portion of the Great Northern Railway had only lasted 2½ years. The rails which replaced these in 1863, guaranteed for seven years, were not taken up finally till 1870; in the meantime, however, a great portion of them had been renewed, so that the average life was only about 5½ years. The life of rails was entirely a question of tonnage, and of speed and frequency of the trains. Thus, on the Loop line of the Great Northern Railway, from Peterborough to Gainsborough, which was opened in 1848, and where the traffic was much smaller than on the main line, the earliest renewals of the rails occurred in 1868, and only within the last year had the up line been renewed throughout. In the down line some of the original rails were still in the road after twenty-eight year's wear, during which period about thirty-nine million tons of traffic had passed over them. The East Lincolnshire section of the Great Northern Railway was opened the same year as the Loop. Only twenty-one per cent. of the up line and four per cent. of the down line had been renewed, the rails still in the road having a considerable amount of wear in them. The tonnage over these rails had been 13,400,000 and 14,300,000 tons on the up and down lines respectively. During the last ten years 85 per cent. of the mileage of the Great Northern Railway had been renewed, and the average life of the rails was nearly sixteen years. With this average life of iron rails, and assuming that sleepers lasted eight years, the estimated average cost of renewals per annum would be £128.90 per mile of single line, while the actual cost had been £139.55.

Steel rails were first laid on the London and North-Western Railway at Camden Town, in 1862, and at Crewe Station in the following year. Diagrams were exhibited showing the wear and amount of tonnage which had passed over the latter. On an average, it appeared that a wear of one-sixteenth inch of the tables corresponded to a traffic of 9,370,777 tons. On the Great Northern Railway steel rails were first used at the coal sidings at King's Cross, but the tonnage over them could not be ascertained. In February, 1867, steel rails were laid in the up and down lines in Maiden-lane tunnel. On the down line the traffic was of a heavy character, consisting chiefly of shunting. A diagram was exhibited showing the worn outlines of these rails, the tonnage over them, and the chemical constituents of the steel. The traffic corresponding to a wear of one-sixteenth inch of the tables varied from 5,251,000 to 31,061,000 tons. Similar diagrams were exhibited, showing the wear, the tonnage, and the chemical analysis of steel rails on other portions of the Great Northern Railway. Steel rails were first laid in the running road in 1866-7, on the up line, near Hornsey. A template of one of these rails was exhibited, showing a wear of only 0.15 inch during a period of 9½ years, the traffic having been 66,546,000 tons, equivalent to 27,727,000 tons for every one-sixteenth inch. The proportion of carbon in this rail was only 0.320 per cent. The analyses for this communication were all made by Mr Riley.

The Metropolitan Railway was opened in January, 1863, as far as Farringdon street, and the extension to Moorgate street in 1865. The greater part of the steel rails had been worn out, and, in some cases, twice renewed, owing to the enormous traffic. The renewals chiefly occurred near the stations, where the brakes attained their maximum effect, that was, intermediate between the points where the brakes were first applied and the station platform. Diagrams were shown of the worn outlines of these rails, of the tonnage over them, and also of the chemical analyses of the steel—the most noticeable features being in the case of the rails in the Clerkenwell tunnel, where a considerable difference in the wear was observable in the wet and dry portions of the tunnel, although the amount of traffic was the same.

In a recent paper, the process of hammering the ingot had been recommended in preference to first cogging it, and then rolling it into the finished rail, the latter process having, it was stated, the effect of injuring the metal. The author had had some experiments made at Mr. Kirkaldy's, with a view of practically testing the relative merits of the two systems. The results of these experiments showed, that the rails rolled direct from cogged ingots had decidedly the advantage, being about 2½ per cent. stronger on the average than those rolled from hammered ingots. On the Great Northern Railway rails rolled from "cogged" ingots had endured ten years of the heaviest traffic, and were still in a serviceable condition.

The author had also made experiments as to the relative strength of deep and ordinary fish-plates. The results showed that the average strength of the deep fish-plate was sixty-seven per cent. of the strength of the solid rail, whereas the average strength of the ordinary fish-plate was only twenty-two per cent. Experiments were likewise made to determine the transverse strength of steel rails, with punched, drilled, and partly punched and drilled fish bolt-holes; likewise steel rails which, previous to being subjected to punching, drilling, &c., had been thoughened by being plunged in water when hot. It was thus ascertained that the strength of steel rails not subjected to the toughening process, with holes punched cold in the ordinary way, was 65.39 per cent. of that of the solid rail; whereas the strength of the rails with drilled holes was 98.68 per cent. and the partly punched and afterwards drilled rails 97.80 per cent. of the strength of the solid rail. The effect of the toughening process was materially to increase the strength of the steel rails, especially the rails with the punched holes, which showed an increased strength of about fifty-eight per cent. as compared with the untoughened punched rails.

In conclusion, the author expressed a hope that in future steel rails would be made of such uniform quality as would insure, as an average, the maximum endurance already met with in some of the instances referred to—about thirty million tons for a wear of one-sixteenth of an inch of the tables. With such a quality of material, the average life of a steel rail would be about 300 million tons, equivalent on the most heavily worked portion of the Great Northern Railway to a forty-two year's life. The effect of this increased duration would be to reduce the present average annual cost of renewals, viz., £213 to about £107 per mile of single line.

THE PROPER DEFINITION OF STEEL.

By RICHARD AKERMAN, Stockholm School of Mines.

From "Iron."

When M. Greiner's proposal for a change in the definition of "steel" was distributed among the jurymen at the Vienna Exhibition, there was not a single voice heard to raise itself in support of the new views, but, on the other hand, it must also be admitted that during the sittings of the jury none took the trouble to seek to oppose them. The reason of this I cannot interpret otherwise than

that the proposal was considered by all as of little value and not worth discussing; but, as several distinguished iron-metallurgists have since shown that they shared M. Greiner's idea, there may possibly be some danger of his views being adopted, and in that case there is an obligation resting on those who differ from him to endeavor, as best as they may, to oppose an alteration which they think likely to be a source of many misunderstandings and mistakes. As I entertain the conviction that M. Grenier's proposal ought merely to be regarded as an unfortunate attempt to legalize the too common *misapplication* of the term, arising from ignorance of the true nature of the products, by including under it the softest kinds of Bessemer and Martin metal, I hope that for the reason already stated it will not be considered superfluous if I attempt to show that the order which M. Grenier believes that he attains by this alteration will, instead, considerably increase the confusion, while complete clearness will, on the contrary, be obtained by the natural development and completion of the old definition.

The supposed advantage of the new definition, according to which *all malleable products* of the iron manufacture, which are obtained in a *state of fusion*, are *steel*, consists in the absence of all uncertainty as to what is steel and what iron. Still more, however, the supporters of the new views with their new definition of steel may be considered to aim at fixing an unmistakable boundary line between the malleable products which are, and those which are not, obtained in a state of fusion; but this object is attained equally well, not to say better, by giving to that which Grenier wishes to call steel, the name of "ingot-metal."

It was Mr. E. Williams who first proposed that Bessemer rails, to distinguish them from rails of puddled iron, should be called "ingot-rails," and Tunner has since recommended the appellation ingot-metal for all malleable iron and steel which have been in a state of fusion. The word "ingot-metal," which, undeniably better than the word "steel," expresses the fact that the product has been in a state of fusion, and while in that state been run into ingots, has the real advantage of not occasioning any change. For this appellation does not cause the least disturbance in the old ideas of steel and iron, but the metal, as it is in accordance with the old views to be considered steel or iron on quite other grounds than the qualities dependent on the state of fusion itself, would come to be called "ingot-steel" or "ingot-iron."

On the contrary, Grenier's new definition of steel, without fixing the boundary line between fused and unfused products better than the word "ingot-metal," would, during a long succession of years, give occasion to much uncertainty and many doubts, for it cannot be believed that the public will be induced to make any hasty alteration of so old an idea as that of steel; but it is plain that, if Grenier's proposal were to be adopted, there would long be an uncertainty as to what in every individual case was meant by this word, inasmuch as it would be understood by some according to the old, and by others according to the new, definition. The sponsors of the new definition have not succeeded in making the uncertainty and want of clearness by which their proposal is characterized a question of the day; but, at the same time, while they try to flatter themselves that the new definition will, by its distinctness, bring about complete clearness, they have in fact seen themselves compelled to retain such appellations as cement and puddled steel, steely iron, &c., and if these still continue to be necessary in the future, we must, in case their new definition of steel be accepted, give up all hope of clearness being attained even in the remotest future.

The advocates of the new ideas make a great ado about the difficulty of being able to make out by the present distinctions if a metal should be called steel or malleable iron, but they may be supposed not to consider in connection with this that, to give a proper idea of the qualities of their "steel," some epithet must be added, as extra soft, soft, half soft to half hard, hard, and very hard. What objection can there be to use, instead of this scale, the following :—Soft ingot iron, ordinary ingot iron, hard ingot iron, soft ingot steel, ordinary ingot steel, hard ingot steel?

The boundary line between ingot-iron

and ingot steel lies at the half-soft to half-hard steel of the new views ; but it cannot be denied that of different persons, according as they fix their attention either on the degree of tempering or on hardness of a different kind and on the capability of welding, one may possibly be inclined to reckon the same product as soft ingot-steel, which the other will call hard ingot-iron, but this inconvenience has prevailed all along since the first production of puddled steel in arranging puddled products, and the men of the new school have as little succeeded in overcoming this difficulty, as they cannot prevent a piece of their "steel" which is called *soft* by one person, from being considered *half soft* by another. What real inconvenience, besides, arises from a rail being called by one an ingot-steel rail, and by another an ingot-iron rail, if all are agreed that it is an ingot rail? and neither the books of works, statistical returns, tariffs, nor such like are grounded on the ideas of steel and iron, but on ingot-metal and not ingot-metal.

Singularly enough, MM. Grenier and Philippart consider that soft ingot-iron for boiler plates and such like purposes, would more easily win confidence if their definition were accepted. For my part, I believe quite the contrary, for the man who all his life has been accustomed to understand by steel a hard and comparatively brittle product, might well, when he knows that he requires a soft and very ductile material, have more confidence in an untried article offered under the name of soft ingot-iron, than in another called soft steel, which appellation for the most part continues to denote a comparatively hard product. The sense of security must always be greater if the appellation ingot-metal be adopted, for the manufacturer can never have the right to understand by ingot-iron a product so hard as that which he can call soft steel.

When Mr. Holley, to show the impropriety of retaining the old system, asks whether there is any reason to call that part of an ingot which is rolled into a rail iron, while another part of the same ingot, which is employed for the production of a tempered tool, is called steel, he is altogether beside the mark, for no one has proposed that the difference between iron and steel should consist in the former being tempered and the latter non-tempered, but the question is only whether the material is capable of taking a temper. If the ingot-rail is so hard, it ought naturally, as well as the tool made from the same ingot, to be said to be of steel ; but if, on the contrary, neither the rail nor the tool be capable of tempering, while, at the same time. they may be welded, they are neither of them steel, but ingot-iron.

A further reason why the new definition of steel ought not to be received, is that between ingot-metal and puddled metal—the latter of which, after Williams, we propose to call "*piled metal*" —there is found a middle class of iron and steel products, comparatively rare, indeed, in most countries, but yet highly deserving of attention, namely the metal produced in the hearth, to which, as is well known, the Swedish iron belongs. Hearth-refining yields a middle product between piled and ingot metal, which I propose to call "*bloom-metal*," inasmuch as it is produced from a bloom which, in fact, has never in its finished state been fused, but which, to distinguish it from puddled iron, has been produced by a partial and successive fusion, the intention of which is to separate the greater part of the scoriæ by which the piled metal is rendered impure. Such bloom-iron, as, for instance, that produced in the Lancashire process, is certainly not so homogeneous and free from scoriæ as ingot-iron, but it commonly lies closer to it than piled iron, and ought therefore rather to be placed under the "steel" of the new views than under their "iron." Properly, however, this division, which has been altogether overlooked by Greiner, &c., belongs neither to their steel nor iron, but ought, as we have said, to form a separate middle class, "bloom-metal."

The overlooking of the last-mentioned middle class, perhaps, besides, has also conduced to the exaggeration of which MM. Greiner and Philippart are guilty when they state that the tensile strength and the ductility of that which they propose to call "steel," are always so much greater than of that which they call "iron," that those who have not themselves had an opportunity of seeing whether the product had been in a state

of fusion or not, may easily settle this question by means of mechanical tests. Without being disposed to deny that the qualities of homogeneity and freedom from scoriæ, distinctive of ingot-metal or Greiner's steel, conduce in general in a very considerable degree to a simultaneous increase of both the absolute tensile strength and the ductility, I consider myself entitled to maintain that experience has sufficiently shown that so many other circumstances are found to have an effect upon it, that it will beyond all question be more difficult to make out by means of mechanical tests whether a product ought to be called steel or iron, than to determine by trying whether it will temper or weld to which kind it ought to be reckoned according to the old idea of steel. Indeed, without the help of such trials, it is in most cases easier to determine whether a product according to the old views ought to be called steel or iron merely by mechanical tests, than by means of the same tests to settle the question according to the new views, for the increase in tensile strength, with the accompanying diminution in ductility, which is caused by an increased content both of carbon and of some other substances, is more regular than the differences between the tensile strength and ductility of products approximately of the same hardness, but produced in different ways.

The examples quoted by M. Philippart indeed, appear to contradict this statement, but they are too exceptional for any well-founded conclusion to be established by means of them alone; while on the other hand, a careful study of the tables belonging to Styffe's experiments on the elasticity, ductility, and tensile strength of iron and steel, and of similar tables published by Kirkaldy and several others affords support to the statement made above.

Far from being able to support the adoption of the new definition of steel proposed by M. Greiner, I must instead, for the reasons stated above, recommend a development and completing of the old idea, as a result of which the products obtained from iron ores will be arranged in the following way:

Malleable.					Non-Malleable.
Piled Metal.	Bloom Metal.	Ingot Metal.	Cement or Blister Steel.	Malleable Cast Iron.	Pig-iron.
Produced by the welding together of unfused particles.	Produced in the hearth either from ore or from pig-iron.	Produced in a state of fusion.			
Piled Iron. Piled Steel.	Bloom Iron. Bloom Steel.	Ingot Iron. Ingot Steel.			
Piled metal may, besides, be produced either from unfused iron sponge obtained directly from ore, or, as the case commonly is, by puddling pig-iron, when the product, in place of piled iron or piled steel, may also be named puddled iron or puddled steel.	When the hearth process by which the bloom has been produced, is wished to be stated, for bloom is substituted Catalan, Lancashire, Franche, Comté, or such like.	When the way in which the ingot has been produced is wished to be stated, for ingot is substituted Bessemer, Martin, Crucible, or such like.	Produced by cementation from piled iron, bloom iron, or ingot iron.	Produced by cementation from pig iron.	

THE CANAL DU MIDI.

From "The Engineer."

A GLANCE at the map of France will show that a comparatively narrow strip of land separates that portion of the Mediterranean known as the Gulf of Lyons from the Bay of Biscay. The extreme width of this strip of land, measured in a direct line at the narrowest place, is about 240 miles, and it includes some of the richest provinces in Southern France. Ships proceeding to the East, because of the interposition of this French territory, are compelled to sail round Spain, and enter the Mediterranean through the Straits of Gibraltar. This represents an addition to the length of the voyage of about 800 miles. Many years ago a proposal was made to construct a canal connecting the Bay of Biscay with the Gulf of Lyons; nothing came of the proposition, which has been renewed several times. The last proposition of the kind emanates from M. Manier, of Oxford, and as this gentleman appears to have worked out his ideas with care, his proposals are just now attracting a good deal of attention, and deserve some notice in our columns. If our readers will once more refer to a good map of France they will see that water communication already exists along the route which such a canal as M. Manier proposes must take. A long inlet or arm of the sea runs obliquely inland from Royan to Bourg, at which place the Garonne debouches. This river rises in the Pyrenees, and at Toulouse is a stream of considerable size. From Toulouse, in an opposite direction, runs the canal of Languedoc, which enters the Gulf of Lyons near Cette. The accommodation provided for boats by the Garonne and the canal is, however, very limited. M. Manier proposes to construct a great ship canal which should start at Bordeaux, about twenty miles from the outfall of the Garonne, and run thence through Agen, Toulouse, Carcasonne, Narbonne, and terminate in the Gulf of Lyons somewhere near Narbonne. The length of the canal would be from Bordeaux to Agen seventy miles, from Agen to Toulouse sixty miles, from Toulouse to Carcasonne sixty miles, and from Carcasonne to the sea thirty-five miles. The entire length of the work would, therefore, be not less than 225 miles, and would in all probability be more, because an approximately straight line could hardly be maintained. The canal would be 300 feet wide and thirty feet deep throughout. Taking into consideration the great length of the work, its depth, and its width, it is evident that M. Manier's scheme is the most gigantic of its kind that has ever been seriously put forward by an engineer. It is difficult, indeed, to realise the magnitude of the operations contemplated, while it is impossible to form anything more than an exceedingly rough estimate of their cost.

We are unable to say much concerning the contour of the ground to be traversed. It is certain that from Toulouse to the Bay of Biscay the ground falls continuously. From Carcasonne the incline is in the opposite direction to the Gulf of Lyons. The highest point in the route is probably reached not far to the south-east of Toulouse, and it becomes apparent that unless locks are constructed much of the canal would have to be made in deep and impracticable cuttings. It is almost impossible, however, to criticise M. Manier's scheme, or, indeed, to deal with it at all until very careful surveys have been made of the country to be traversed right and left of the proposed line of the canal. It must not be assumed that because the Garonne is navigable for small craft as far as Agen, while ships of considerable dimensions can reach Bordeaux, it will prove in any way suitable for a maritime canal. Indeed, it is quite possible that such difficulties might be encountered in straightening and deepening its channel, removing rocks, &c., that it would be better and cheaper to abandon the river at once, except as a feeder, and construct a totally new channel. Nothing is more delusive than the idea of utilizing rivers in the formation of canals; the very presence of water throws great difficulties in the way of attempts to modify the bed of a stream, and these difficul-

ties augment with the dimensions of the river. Even if we take for granted that the Garonne will lend itself readily to M. Manier's purpose, this would take him little more than half way; for the utilization of the Languedoc Canal is, of course, out of the question. It would be simply improved off the face of the earth if it were touched at all. It may, however, be assumed that there are no obstacles of such a nature that they will prevent the formation of a navigable canal from Bourdeaux to Narbonne —that is to say, no mountain range has to be traversed; a furrow has not to be scooped through a sandy desert; no pestilential marshes have to be crossed. The climate is delightful; the supply of labor would be tolerably abundant, and the quality of the labor very fair. Materials of all kinds would be readily accessible. Nothing, in short, stands in the way of the construction of M. Manier's canal but its cost. What this would be it is impossible to say, but it cannot fail to be enormous. What would be obtained in return for this outlay?

It is clear that the canal can only be constructed as a national work, or as a private undertaking. In the first case indirect returns would suffice, and profit, in the commercial sense, would not necessarily be sought. We confess, however, that we see no reason why France should make a ship canal in the way proposed. The advantages which she would derive must be small, so small that they would lack national importance. It is true that M. Manier claims that his canal would for ever free Southern France from inundations, on the ground, we presume, that as the Garonne could be merged and lost in the ship canal, it could no longer overflow its banks, and this, no doubt, would be a material gain. He also explains that there would be available for irrigation or power 21,000,000,000 of cubic yards of water per year. We venture to think, however, that these statements have not the solid basis of fact which would alone entitle them to serious consideration. The flood waters now poured into the Garonne must equally be poured into the canal, and they may there prove a source of serious trouble and perplexity. The existence of a strong current in a maritime canal would suffice to render the canal useless for its intended purpose, to say nothing of the ruin it would create in the banks on either side. Yet, unless a sharp current is permitted in flood time to traverse the canal, the canal must be made of a capacity two or three times greater than would suffice if there were no floods. There is no escape from these difficulties. Either the canal will be practically independent of the drainage of the country which it traverses, in which case it will not prevent inundations; or it must act as a great main drain, in which case water will run at a high velocity between its banks in winter. It has yet to be proved, in a word, that it is possible to combine the functions of a river and of a ship canal. As regards the supply of water for irrigation or motive power, M. Manier is yet more obscure, so obscure that we have no means whatever of criticising his assertions. At the best, then, it would appear that the only national advantages France could gain would be the prevention of inundations, and the supply of water for irrigation or power. This, however, will, as we have said, in no way recoup France for an outlay of many millions. If we consider the construction of the canal as a private speculation, it is all but impossible to arrive at any definite conclusion. As regards local traffic, it is certain that the canal could not compete with a railway, except, perhaps, for very heavy goods. But we have yet to learn that any traffic exists between the different towns on the route of the canal which could supply more than an infinitesimal income. The whole profits of the canal must then be derived from the tolls levied on ships passing from the Gulf of Lyons to the Bay of Biscay and *vice versa;* and there are absolutely no reliable data as to what tonnage would pass through the canal in a year. The canal would depend almost entirely on England for its traffic. M. Manier estimates that in 1880 England would send six millions of tons through it; but it is very easy to see that no reliance can be placed on such an estimate, for the simple reason that the advantage to be gained would not be so great that merchants would consent to pay a high tariff, while on the

other hand a high tariff might be essential to the success of the canal as a mercantile speculation. No analogy exists between the Canal du Midi and that of Suez. The saving effected in distance by the latter is a question not of hundreds but of thousands of miles, and the Suez Canal not being more than one-fourth of the length of the proposed French canal, a tariff of one-fourth the amount required to maintain the French canal would suffice to defray its expenses. It is unnecessary, we believe, to pursue the subject further. We have noticed it at some length, because it is a splendid engineering enterprise; but, as matters stand, it is simply a magnificent dream. Before M. Manier can expect to obtain a fraction of capital he must be prepared to show that not only can the Canal du Midi be made, but that it can be maintained and worked, we will not say with a certainty of profit; but he must at least convince the world that a fair prospect of realizing profit has an actual existence.

THE CHEMICAL TEST OF WATERS.

From the "Universal Review of Mining."

To judge of a water for drinking purposes it is necessary to take especially into consideration the substances which indicate that it has been polluted by feculent matter; that is to say, by organic matter; ammonia, nitrous acid, nitric acid, chlorine (arising from the salt which enters into our food) and sulphuric acid.

The report of the Commission appointed by the municipal council of Vienna to take into consideration the supply of water, enumerates the conditions which water intended for the use of important towns ought to fulfill, as follows:

1. A water to be entirely unobjectionable ought to be clear, pure and inodorous.

2. It ought to contain but little solid matter, and, moreover, absolutely no organized matter.

3. The amount of alkaline earths ought not to correspond to more than 18 parts of lime in 100,000 parts of water (0.18 grammes C a O (2.77 *grains*) per litre).

4. The compounds directly soluble in water ought not to enter but to a small fractional part into the amount of saline matter. The nitrates and sulphates ought not, moreover, to be found in it in any large quantity.

5. The chemical composition and temperature of the water ought to vary but very little with the seasons.

6. All influx of foreign matter ought to be avoided.

7. It is only water from a fresh spring which satisfies these conditions; and this alone is fit to supply water for drinking.

8. Water suitable for industrial purposes ought to fulfill nearly the same conditions.

9. River water filtered serves for manufacturing purposes if it can at all times be obtained pure; but it cannot be used for drinking, since it does not fulfill conditions 5 and 6.

10. All water that is inodorous and which does not contain any considerable quantity of putrid matter, will serve the purposes of watering and cleansing the streets.

According to Pettenkofer, water fit for drinking ought not to contain, in 100,000 parts, more than five parts of organic matter destructible by permanganate of potassa (50 milligrammes per litre corresponding to 10 milligrammes $K_2 Mn_2 O_8 = 2.5$ milligrammes of oxygen) and Kubel admits only from 3 to 4 parts. It is the opinion of Almen that good water ought not to require for its oxydation more than 0.3 of oxygen for 100,000 parts of water, and to be employed for ordinary purposes, it ought not to require more than 0.6 (1 part of oxygen = 20 parts of organic matter). These last figures are, undoubtedly, too high, or applicable only to waters of turfy soil. Reichardt, admits for water as an aliment only from 2 to 4 milligrammes of permanganate per litre.

In the bad water from the wells at Dorpat, Schmidt has often met with embryos of *Distoma*, *Botryocephalus*, &c. Lersch, maintains what might otherwise have been doubted, viz., that impure water often propagates the germs of *helminthos*, especially of axarides, tenias, and others; the infusoria and similar organisms provoke relaxation. Following Cohn, water which contains green flag and *diatomus* is free from organic matter producing azote by decomposition, those organisms not being able to live in the presence of such matter. On the contrary, water which contains monads, bacteries, and infusoria, contains azote in the form of organic matter in fermentation and putrefaction. In testing water microscopic researches cannot, then, be neglected.

The reports of the commissions of Vienna, Berlin, and Carlsruhe, make it appear that the nitrates tend to diarrhœa. Muller considered $\frac{1}{10000}$ of nitrate (40 milligrammes per litre) as dangerous; that proportion is sufficient to enable us to discover the nitric acid by means of a sulphate of iron in the residuum of evaporation of 10 cubic centimetres of water. The Commission of Vienna admits but 4 milligrammes; Reich also does the same; while Frankland goes as far as 5 milligrammes of azote=19.2 N_2O_5=22.5 HNO_3. Ekin has proved the presence of nitric acid in water, springing from oolitic beds rich in fossil remains. Rain-water contains as much as 13 milligrammes per litre of N_2O_3; 27 milligrammes of nitric anhydride=31.5 milligrammes HNO_3=7 milligrammes N=8.5 milligrammes NH_3, may then be admitted as a limit. Reichardt considered the determination of ammonia as of little importance, and Fleck, attached to it, on the contrary, a special importance. Ammonia and nitrous acid being unquestionably the produce of putrefaction, it is reasonable that water which contains them in such considerable quantities should not be considered as drinkable.

Reichardt is of opinion that more than 8 milligrammes of chlorine per litre is remarkable. The water from a spring in the Thuringer-Wald has given in an analysis 1.5 to 2.1 milligrammes of chlorine; the water from a well in the vicinity of Hanover contained 15 to 35 milligrammes, and that of another well, near the salt-works of Badenstadt, 56 milligrammes. We may consider, from this, 35.5 milligrammes of chlorine (atomic weight expressed in milligrammes) as a limit for Hanover.

In good water the quantity of sulphuric acid varies from 2 to 50 milligrammes. Reichardt considered more than 63 milligrammes per litre as dangerous, the more so as in a hygienic point of view, on account of the action of the sulphates of potassium, sodium, and magnesium upon the constitution, as well as in a manufacturing point of view, on account of the inconveniences of the sulphate of lime and magnesia, 80 milligrammes of sulphuric anhydride=98 milligrammes H_2SO_4 per litre (molecular weight expressed by milligrammes), may be considered as a limit for good drinkable water.

Johnson says: "It is very clearly shown, by the impurities of the waters of springs and rivers, that the matter contained in those waters is the most favorable to the wants of living creatures." This is at least a singular idea.

Letheby and Wilson give it as their opinion that hard water is clearer, colder, contains more air than soft water, and is less capable of assimilating itself to organic substances (?), sustaining the life of living organisms and dissolving iron and lead. In a physiological point of view, calcareous salts preserve living beings from several injurious influences. The human body demands a certain quantity of phosphate and carbonate of lime. The first of these compounds is furnished in sufficient quantities by ordinary food, and the second by waters from the spring and the river. The mortality of large towns is inversely proportional to the hardness of the water. The average hardness of the water of London and twenty-four other towns of England is 16° English; at Edinburgh, Leith, and others 8°; at Dundee, Glasgow, &c., from 1.3 to 3.8°. In the towns of the first group, the average mortality is from 21.9 per thousand; in that of the second group 24.9 per thousand; and in that of the third 26.1 per thousand. Water at 6° (=4.8° German) is suitable for all domestic and manufacturing purposes. Berlin, in spite of the hardness of its water (14° to 61°) has a

mortality of 38.9 per thousand; at Magdeburg, the mortality is about 33 per thousand, although the hardness of the waters is from 27° to 70°. The law laid down by Letheby and Wilson is not, then, of general application. This need not astonish any one, for we have seen the great hardness of waters in the neighborhood of towns arising often from their being strongly polluted.

Boussingault, considers lime as essential to water for drinking, but Friedleben has discovered in the data of Boussingault errors of calculation, and, correcting these, he has arrived at an opposite conclusion. The Commission of Vienna gives the preference to a soft water containing a maximum of 0.18 grains of lime per litre. Reichardt is of the same opinion; he remarks, meanwhile, that a sample of water from Muschelkalk, pure in every respect, has given in a test 23° of hardness. Schmidt also prefers a soft water. According to Frankland, it is the general opinion in England that the water is more wholesome in proportion as it contains a less quantity of salts. In Brazil, and also in China, the same opinion prevails; so much, indeed, that, according to Staunton, the Chinese of high rank drink distilled water. Grahn considers water free from all foreign substances as the best, and then he adds, that distilled water is insipid and indigestible, which last remark is evidently incorrect. Lersch enumerates a great number of diseases attributed to the use of hard water.

As regards the salts of magnesia, it may be positively stated that the water in which they exist in a considerable proportion is dangerous. The limits of a good drinkable water may be fixed at 40 milligrammes of magnesia and 112 milligrammes of lime, and, consequently, 16.8° of hardness.

We have yet to consider the gaseous elements. We say, in general, and not without reason, that water agreeable to the taste cannot be wholly free from oxygen and carbonic acid (the latter under the form of bicarbonates); but these elements are not indispensable to render the water fit for use. The waters from ordinary wells do not generally contain the carbonic acid in a free state.

A good water to be drinkable, ought then to fulfill the following conditions:

1. It ought to be pure, without color, and inodorous.

2. Its temperature ought to vary only between narrow limits with the seasons (6° to 12°).

3. It ought to contain but very little organic matter and absolutely no organism.

4. It ought to contain neither ammonia nor nitrous acid; the nitrates, sulphates, and the chlorides ought not to exist in it in a large quantity.

5. It ought not to be too hard; it ought not especially to contain the salts of magnesia in a considerable quantity.

The following quantities of different substances per litre may be admitted as limits for a good drinkable water.

Organic matter: 0.25 of the equivalent expressed in milligrammes (40 milligrammes = 2 milligrammes O = 8 milligrammes $K_2 Mn_2 O_8$).

Nitric acid: 0.5 of the equivalent expressed in milligrammes (27 milligrammes $N_2 O_5$ = 31.5 milligrammes H N O_3).

Chlorine: 1 equivalent in milligrammmes (35.5 milligrammes).

Sulphuric acid: 2 equivalents expressed in milligrammes (80 milligrammes S O_3 = 98 milligrammes $H_2 S O_4$).

Magnesium: 2 equivalents expressed in milligrammes (24 milligrammes Mg = 40 milligrammes Mg O).

Calcium: 4 equivalents expressed in milligrammes (80) milligrammes Ca = 112 milligrammes Ca O); then we have 16.8° of hardness.

Under certain circumstances, a water containing 1 equivalent of nitric acid, 2 equivalents of chlorine, and 8 equivalents of lime, may be considered as drinkable. It is evident that the wholesome state of water cannot be ascertained by the determination of only one of its elements. Of two samples of water which have been equally polluted by feculent matter, one may contain but little organic matter while the other will contain a large amount, the latter will have a weak affinity for nitric acid and ammonia, while the former will contain a large proportion of those compounds; this will depend upon the nature of the soil. The tests made from only one point of view, such as de-

composition by nitric acid, by Reich and Goppelsroder, that for organic matter by Almen, or the microscopic test proposed by Bischoff, can have only a limited value.

When a person has to form an opinion of a water it is often an assistance to compare it with water taken from a spring in the same geological formation, and which is known to be quite free from fecal matter. According to Reichardt, a litre of water contains on an average:

	Organic matter.	Nitric Acid.	Chlorine.	Sulphuric acid.	Lime.	Magnesia.
In Granite	15.7	0.0	3.3	3.9	9.7	2.5
In Schist	6.0	0.5	2.5	24.0	50.4	7.3
In Muschelkalk	9.0	0.2	3.7	13.7	129.0	29.0
In Dolomite	5.3	2.3	trace	0 to 340	140.0	65.0
In Gypsum	trace	trace	16.1	1108.2	766.0	122.5

Lastly, the storage and conveyance of water has to be considered, especially in the case of leaden pipes. Lissauer has discovered that the protecting layer, which forms itself by the prolonged contact of the water with the lead, does not, till after one week, attain sufficient thickness that the water may not any longer absorb parts of the metal. The injurious action of the leaden pipes has not yet been completely elucidated.

Water from marshes has, for a long time, been acknowledged as entirely unsuitable for drinking. The Koran represents the use of stagnant water for a beverage as one of the modes of punishment in the other world.

It is, then, spring waters, and waters from sand not soiled with animal matter, which satisfy the conditions of a good drinkable water. It is evident that of all the waters of the city of Hanover, the analyses of which have given the most favorable results, not one may be cited as good, and very few are passable. No plan for a supply of water has, for years, been proposed, which is sufficient to remedy this state of things.

In judging of water intended for the supply of boilers, it is necessary to take into consideration—

1st. Matter forming incrustations which are dissolved in the state of bicarbonates, and are, for the most part, precipitated by heat in the form of simple carbonates, as, for example, carbonates of lime and magnesia of variable hardness. Chevalet and A. W. Hoffmann say, that in a litre of water 0.034 grammes of carbonate of lime, and 0.106 grammes of carbonate of magnesia remain in solution.

2d. Matters almost insoluble, which are, in consequence, separated by the evaporation of the water. We may cite gypsum as an example of this kind. Helm discovered in the water of Prangenau, sulphates of sodium and potassa, but not of gypsum; lime and magnesia existed only in the form of carbonates.

In treating, therefore, the sulphuric acid as a sulphate of lime, and representing the remainder of the calcium as a carbonate, a false result would be obtained. It is here that we ought to determine the quantity of crustaceous matters which can be separated by heat or lime, and in what proportion they exist. These being found in the form of sulphates must be separated by sodium, &c.

I cannot comprehend that assertion that the springs of Fischborn, near Frankfort, contain, in 100,000 parts, 0.24 of sulphuric acid, combined with lime, and 0.59 of soda, combined with chlorine and carbonic acid; that is to say, of carbonate of soda and of sulphate of lime at the same time.*

For water for manufacturing purposes and domestic use, the capability of retaining organic matter is much less important than that of salts of lime and magnesia, that is, the hardness of the water. Soft water is necessary for boiling vegetables, especially the hard luguminous kind; also for the preparation of tea and coffee; and for washing (100 litres of water, 30° of hardness, decomposing 360 grammes of soap), scouring silk, for manufacturing paper, for tanneries, dye-works, and for factories of paste, &c.

It is maintained that the excellence of the Vienna beer is principally due to the use of soft water; the English, on the

* It is not impossible if the soda is in the form of a bicarbonate.

contrary, declare that the gypsum contained in the water of the Trent, is necessary for the preparation of Burton ale, so celebrated throughout the world. When the water does not contain gypsum it is added, in consequence of the ferment not being fully developed except in water containing gypsum. A strong fermentation may be moderated by a larger addition of gypsum ("Bierbrauer," iv, 71, in which volume some remarks are also given upon the injurious effects which organic matter, ammonia, &c., produce in the manufacture of beer). The alkaline salts, which are very soluble, also the chlorides, which liquefy calcium and magnesium, render walls humid, detach the plastering, and spoil the tapestry; a plastering impregnated with saltpetre is irremediable.

A person may say that the hardness of water is not to be taken into consideration in the construction of buildings; but water abounding in chloride and nitrate ought never to be employed for that purpose.

It is scarcely possible to point out the limits in which waters are suitable for domestic and manufacturing purposes.

DOUBLE-ENDED SHIPS OF WAR.

From "The Engineer."

When ships are so constructed that bow and stern become interchangeable terms, and it is a matter of indifference which extremity goes first, they are said to be "double-ended." Why we shall not attempt to say. The most familiar examples of this type are to be found among the fleet of passenger steamers which navigate the Thames above London Bridge. In the United States vessels of great size constructed in this way are used as ferry boats; but the Bessemer is, perhaps, the largest double-ended boat ever built. The type is by no means unknown to naval architects, and these gentlemen understand very clearly what are the best lines that can be given to craft of this kind. It is hardly necessary to say that it is impossible to so form a double-ended ship that she can be propelled at a given velocity with as little power as would suffice if she was built on ordinary lines. But when due care is exercised to obtain a favorable result, a very high speed may be got from a double-ended ship without an extravagant consumption of fuel. In other words, although the type is not that best adapted for speed, there is no inherent defect in it which renders the attainment of a reasonably high velocity, with a moderate expenditure of power, impossible. As regards sea-going qualities, such as steadiness and dryness, a double-ended ship can be built which will be equal in most respects to any ordinary vessel. In a word, while we do not dispute that double-ended ships have certain disadvantages important enough to prevent their extended adoption, we maintain that these defects are in no sense so grave as to prohibit the employment of the type when circumstances warrant a departure from ordinary practice.

It is a somewhat remarkable fact that among all the designs for war-ships which have been discussed by British Admiralty Boards, the double-ended type has been totally neglected. As we do not possess access to the pigeon-holes of Whitehall—the limbo to which the rejected communications of the outside world are relegated—we are unable to say whether designs for double-ended war-ships have or have not been submitted to the Admiralty; but whether they have or have not, it is at least certain that the construction of a ship of the type on a large scale has never been seriously discussed. The only vessel of the kind in the British navy is the little Waterwitch. A proposal to build such a ship has not found its way into any Blue-book or published official document; and so far as we are aware, this is the first occasion on which the construction of a large sea-going double-ended iron-

clad ship has ever been suggested in a journal. We are aware that a thousand objections may, and probably will, be urged against the idea; but we venture to assert that the more carefully the suggestion is considered, the smaller will the objections to it become. That there are objections we do not pretend to deny; but if it can be shown that these objections are based only on the existence of defects which become insignificant under the given conditions, while very important advantages are obtained which can be had in no other way, we think we may claim to have made out a good case for the double-ended ironclad. Now, the objections to the double-ended system are that the form is unfavorable to speed, and that it is difficult to apply the propelling power in any way except by paddle-wheels, which of course, can not be used in a ship of war. Very few experiments have been made to settle the first point. It is true that the fine lines suitable for a bow are not the rather full lines best adapted for a stern; but, on the other hand, it can scarcely be denied that these very fine lines are far better adapted to supply a screw with water than are the lines of an ordinary after body. Even if this were not the case, however, it remains to be proved that the resistance of a properly designed double-ended boat is really seriously greater than that of a properly designed ship of the usual type. For the purpose of argument, however, we may grant that, whereas a fast ocean steamer, with a displacement of 5,000 tons, will attain a speed of fifteen knots with 4,000 horse-power, a 5,000-ton double-ended ironclad will only attain a velocity of fourteen knots with the same power. What follows? Are we to assume that because the form of our double-ended ship is so defective that she steams at but fourteen knots instead of fifteen knots, she is to be regarded as a failure? Such an argument would be absurd. It is open to question whether it would be possible, under any conceivable circumstances, to drive Popoffka or circular ironclads at twelve knots an hour; but there is no reasonable doubt that double-ended ironclads could be built, which, other things being equal, would not be a knot an hour behind the fastest ironclads in the British navy. If the speed of such ships was limited to even ten or eleven knots, it would not preclude them from playing a very important part in a naval engagement. The objection that it is difficult to supply double-ended vessels with instruments of propulsion is better founded, and deserves more consideration than questions of relative speed. It is evident, however, that a screw may be fitted in the dead wood at each end, and that the screw for the time being working at the bow will not be much worse off than that at the stern of an ordinary ship. It would not be worse off at all were it not that the water which it will throw astern must run along the sides of the ship and augment skin friction. Having regard to the fact that it will obtain solid water in all the quantity it can require, it will be, in one sense, much more efficient than any screw working at the stern of a vessel can be. Apart from all this, Mr. Griffiths may be able to combine two screws in a tunnel, as he has suggested, in such a fashion that no loss of power will be incurred. It is obvious that the engines present no difficulties. A set of boilers about amidships, with a pair of engines forward and another aft, would drive the screws independently; and a ship so fitted would have the advantage of possessing duplicate propelling mechanism, so that if one screw or set of engines was disabled, the other would remain available. We think we shall not claim too much if we ask our readers to admit that a double-ended, double-screw ship can be built which will be able to keep her station with any save one or two of the fastest men-of-war in the world, and this without burning so much coal that she will have to seek a port before any of her consorts.

The advantage possessed by a double-ended man-of-war is that such a vessel would possess far beyond any war ship afloat the power of manœuvring; and while she would be quite as "handy" and as easily steered as any other class of ship, she would require infinitely less steering. The smartest ironclad afloat cannot at full speed be turned round in much less than six minutes, during which time she will traverse nearly a mile. A double-ended ship could remain within the circle thus described by an ordinary antagonist, and continually keep end on to her, by simply moving a few yards

ahead and astern on various radii or diameters of the circle. A double-ended vessel, again, might venture into a harbor or channel, certain that she could get back without turning round if necessary, into which an ordinary vessel dare not enter. If she attacked and broke the enemy's line of battle, instead of having to steam away and lose time, worth millions at a critical period in a naval action, in turning round, she would, when she had passed the enemy's ships, be in a position to repass them in the opposite direction without a moment's delay. The field of her operations would be the smallest possible—a matter of incalculable advantage in waters thickly sown with torpedoes. It is, however, as a ram, that a double-ended ship would possess a supreme advantage. If a vessel of the ordinary type misses her blow a long period must elapse before she can get the chance of delivering another, which will be spent in turning round. Not so with the double ram. The very method of eluding an attack in the first instance adopted by a foe may leave that foe helpless against a second attack from a vessel which has practically no limit to the rapidity with which she can make charge after charge. We need not extend our arguments in this direction. We fancy that every naval officer will see at a glance that a double-ended ironclad would be all but ubiquitous in a naval action, the shortest and handiest ships ever built by Mr. Reed being as mere logs on the surface of the water as compared with a ship which never required to be turned round.

It will, of course, be argued that it is impossible to make a double-ended ram with a screw and a rudder at each end. This has to be proved, and we do not believe it can be proved. To go into the reasons which lead us to say that we see no insurmountable difficulty in the matter would be out of the question here. We are not writing a treatise on a new type of ironclad, but simply suggesting that the type deserves the best attention of those who design ships of war. It will suffice to say here that rams may be so constructed that they may be used efficiently without endangering screws far behind them, that it is not essential that such steering as a double-ended boat would require in action should be done with rudders, and that even the screw might be dispensed with. The question is one which, for the present at least, may safely be left in the hands of the competent naval architects who abound in England. On another occasion we may, perhaps, have something more to say on the subject.

LIGHTHOUSE. — The Dhu Heartach Lighthouse has been recently completed upon a rock off the Western coast of Scotland, fourteen miles from land. The light is built upon a trap-rock two hundred and forty feet long, and one hundred and thirty feet broad, which rises about thirty-five feet above high-water mark. The tower is in form a parabolic frustum, surmounted by a plain cavetto, abacus, and parapet, the upper course of which is one hundred and seven and a-half feet above the foundation. The doorway is thirty-two feet above the foundation. Three thousand one hundred and fifteen tons of granite have been used in the construction, one thousand eight hundred and forty of these tons being used for the solid base; the stones being laid in Portland cement, and joggled together with cast and malleable iron joggles. Work was begun in 1867; but, owing to the extreme difficulty of effecting landings, little was accomplished; in 1868 landings were effected only on thirty-eight days, and, in 1869, upon sixty days. Early in June, 1869, the first courses of the foundation were laid; but, even though cemented and joggled, a gale detached more than a dozen stones, each weighing over two tons, although they were at a height of more than thirty-five feet above high water mark. All the cutting and fitting was done on shore; and the stones, when properly fitted, were placed upon lighters, and towed out to the rock. In 1870, landings were effected on sixty-two days, and, in 1871, on thirty-seven only. In 1872, the building was completed, and the light put in: this is one hundred and forty-five feet above the sea, and can be seen from a distance of eighteen nautical miles. The cost of the lighthouse, exclusive of the other buildings on the mainland, was more than $357,000.

ON THE THEORY AND CALCULATION OF CONTINUOUS BRIDGES.

By MANSFIELD MERRIMAN, C. E., Ph. D., Instructor of Civil Engineering in the Sheffield Scientific School.

Written for Van Nostrand's Engineering Magazine.

I.

When a straight bridge consists of several spans, each entirely independent of the others, it is said to be composed of *simple girders*. If, on the other hand, it consists of a single truss extending from one abutment to the other without any disconnection of parts over the piers it is called a *continuous girder*. A load placed upon any span of a continuous beam influences, to some extent, each of the other spans, and hence its complete theory is much more complex than that of the simple one. This very complexity however has rendered the subject an attractive one to mathematicians, who, pursuing science for science's sake, have investigated the laws of equilibrium which govern it. These laws with the many beautiful consequences attending them form one of the most interesting chapters of mathematical analysis, and as such have interest and value independent of their application in engineering art.

It is the object of the present paper to present in as simple a form as possible some of the main principles and laws most needed by the engineer, and to illustrate their application as fully as space will permit to the practical designing of continuous bridges.

Chapter 1.

The first point to be observed in considering either a simple or continuous girder is that all the exterior forces which act upon it are in equilibrium. The exterior forces embrace the weight of the girder and the loads upon it which act downward, and the pressures or reactions of the supports which act upward. In order that these may be in equilibrium, it is necessary that *the sum of the reactions of all the supports must be equal to the total weight of the girder and its load.*

Thus, if a simple girder of uniform section and weight rest at its ends upon two supports, the reaction of each support will be one-half the weight. Exactly in the center between the two supports or abutments, let us suppose a pier to be placed just touching, but not pressing against the beam, which, at that point, has a deflection below a straight line joining the two abutments. Then the condition of things is in no way altered, for the weight being W, each abutment reacts with a force $\frac{1}{2}$ W, while the pier bears no load. Raise now the pier so as to lift the girder above the line of deflection and it receives a part of the weight W, while the reactions of the abutments become less than $\frac{1}{2}$ W. If the pier be raised higher and higher, it will at length lift the girder entirely from the abutments and bear itself the whole load W. In every position, however, the sum of the reactions of the three supports is equal to the total load. For example, when the three are on the same level it may be shown that the reaction of each abutment is $\frac{3}{8}$ W, and that of the pier $\frac{10}{8}$ W.

This illustration shows also that *small differences of level in the supports occurring after the erection of a bridge cause large variations in the reactions of its supports and in the strains in its several parts.* A simple girder having a deflection of one inch, would, if raised one and three-fifth inches at the center, be entirely lifted from the abutments. In the first case the upper fiber would be in compression, the lower in tension; in the second case, the upper would be in tension, the lower in compression. If the center were raised only one inch, the reversal would be only partial, the upper fiber becoming subject to tension for a short distance on each side of the middle. This fact often used as an argument against continuous bridges, is really an objection only when the piers are liable to settle after erection. Differences of level, previously existing, do not act prejudicial when the bridge is built upon

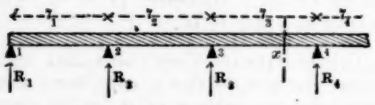
the piers, and with a profile corresponding to them.

The mathematical theory of the continuous girder enables its reactions and internal strains to be found for any assumed levels of the supports, provided only that the differences of level are very small compared with the length of the spans. However interesting such investigations may be in themselves, they are of little importance in practice, since it has been shown that when all the points of support are on the same level, the greatest economy of material results.* In all that follows, then, we shall regard the girder as resting on level supports, or, what is the same thing, that it was built with a profile corresponding to that of the piers.

The loads upon a bridge and the reactions of the supports are *external forces*. The equilibrium between them is maintained by means of *internal forces*, which, in a framed truss, are transmitted longitudinally along the pieces as strains of tension and compression. *When all the external forces are known, these internal forces or strains can be readily found.* This very important point we shall now proceed to illustrate.

Fig. 1 represents a portion of a con-

Fig. 1.



tinuous girder; the first span on the left is called l_1, which also represents its length, the second l_2, the third l_3, etc.; in like manner, the supports beginning on the left are designated by the indices 1, 2, 3, etc., and their reactions by R_1, R_2, R_3, etc. Let the load per linear unit be w, supposed uniformly distributed, then the weight of the first span will be $w\,l_1$, of the second $w\,l_2$, of the third $w\,l_3$, etc. If there are four spans the total weight will be

$$w\,l_1 + w\,l_2 + w\,l_3 + w\,l_4$$

and from the fundamental idea of equilibrium, we must have the equation

$$R_1 + R_2 + R_3 + R_4 + R_5 = w\,(l_1 + l_2 + l_4 + l_5)$$

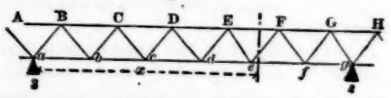
Each of the reactions is then a fraction-

* Weyrauch; *Theorie der continuirlichen Träger*, p. 129. Winkler; *Lehre der Elasticität*, p. 166.

al part of the total load, and by methods hereafter to be explained, their values may be readily computed, whatever be the number of spans. Granting for the present that they may be found, let us inquire how we may obtain the internal forces or strains in any part of the girder.

In the span l_3 let a vertical plane be passed, cutting the beam at a point whose distance from the support 3 is x. All the internal forces acting in this section may be considered as resolved into two components, one vertical and the other horizontal. The sum of all the vertical components is a force which prevents the two parts of the beam from shearing asunder, and is called the *shear* for that section; the horizontal components acting in parallel planes are the resisting strains of tension and compression in the horizontal fibers, and the sum of their moments with reference to any point in the section is called the *moment of resistance*, or simply the *moment* for that section. The internal strains in any section are thus completely represented by the shear and moment. For example, if the girder in Fig. 1 be a framed truss of which Fig. 2 represents the span l_3,

Fig. 2.



enlarged, and the section be passed cutting the three pieces E F, F e, and $e f$, the vertical components of the chord strains will be zero, and that of the diagonal strain e F will be the shear. Hence, if the shear be known, and the angle included between the vertical and a diagonal be θ, we have only to multiply the shear by *sec.* θ to find the strain in the diagonal. Again, let the section be moved to the left so as to pass through the point e, and let that point be taken as the center of moments. Then the moment of resistance will be the moment of the chord strain E F. Hence, if that moment be known, we have only to divide it by the depth of the truss to get the strain in E F.

The internal shear and moment at any section are easily found from the fundamental conditions of statical equilibrium. The shear being an internal

vertical force is the resultant of the exterior vertical forces on either side of the section. The exterior forces on the left of the section, for instance, have for a resultant their algebraic sum; considering the upward forces as positive, and the downward ones as negative we have from Fig. 1, their sum

$$S=R_1-w\,l_1+R_2-w\,l_2+R_3-w\,x$$

as the expression for the shear in the section x. To get the internal moment for the same section, we have only to consider in like manner that it is equal to the sum of the moments of all the exterior forces on either side of the section, for if otherwise, there would be a tendency to rotation. The moment of the force R_1 with reference to x is $R_1(l_1+l_2+x)$, of R_2 is $R_2(l_2+x)$, of the load $w\,l_1$, is $w\,l_1(\frac{1}{2}l_1+l_2+x)$, etc. Thus from a mere inspection of Fig. 1 we write the value of the moment M, regarding those moments as positive which cause a tensile strain in the upper fiber at x, and those as negative which cause a compressive one. The expression is

$$M=-R_1(l_1+l_2+x)+w\,l_1(\tfrac{1}{2}l_1+l_2+x)-R_2(l_2+x)+w\,l_2(\tfrac{1}{2}l_2+x)-R_3x+wx\cdot\tfrac{1}{2}x$$

Now in these expressions for the internal shear S and the moment M at any point x, the lengths l_1, l_2, x are given by the conditions of the case in hand, and the same is true of the load per linear unit w. Hence the shear and moment, and consequently the internal strains are easily obtained as soon as the reactions of the supports are known. We shall hereafter give methods by which the reactions may be readily determined.

By the same reasoning if we pass a section in the span l_2, (Fig. 1) at a point whose distance from the support 2 is x, the shear S and the moment M for that section will be

$$S=R_1-w\,l_1+R_2-w\,x$$
$$M=-R_1(l_1+x)+w\,l_1(\tfrac{1}{2}l_1+x)-R_2x+\frac{w\,x^2}{2}$$

In a simple girder whose length is l_1, and each of whose reactions is R or $\frac{1}{2}\,w\,l$ the shear and moment for any section x will be

$$S=R-w\,x=w\,(\tfrac{1}{2}\,l-x)$$
$$M=-Rx+\frac{w\,x^2}{2}=\frac{w}{2}(-l\,x+x^2)$$

When the number of spans is large, the expressions for the shear and moment as above deduced become long and involve much arithmetical computation. We are, however, fortunately able to place them under a much simpler form. First they may be written thus

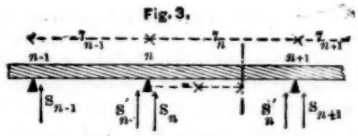
$$S=(R_1-w\,l_1+R_2-w\,l_2+R_3)-w\,x$$
$$M=[-R_1(l_1+l_2)+w\,l_1(\tfrac{1}{2}\,l_1+l_2)-R_2\,l+\tfrac{1}{2}\,w\,l^2]-(R_1-w\,l_1+R_2-w\,l_2+R_3)x+\tfrac{1}{2}\,w\,x^2$$

Now $(R_1-w\,l_1+R_2-w\,l_2+R_3)$ is the shear in the span l_2 at a point infinitely near to the support 3; let this be called S_3. Also the quantity enclosed in [ ] in the second equation is the moment of the exterior forces with reference to the point 3; let this be called M_3. Then the equations become

$$S=S_3-w\,x$$
$$M=M_3-S_3\,x+\tfrac{1}{2}\,wx^2$$

Therefore *the internal shear and moment at any section can immediately be found*, without the necessity of determining the reactions, *provided we know the shear and the moment for the preceding support.* This method, due to Clapeyron, of using the moment at the supports instead of the reactions greatly simplifies the numerical computations of a continuous truss. We designate the moment at 3 by M_3, the reaction being R_3, or the sum of the shear S_3, in the span l_3 and of the shear S'_3 in the span l_2 both infinitely near to the support 3. In like manner the moments at the supports 2 and 4, will be designated by M_2 and M_4, the shears just to the right of those points by S_2 and S_4, and those to the left by S'_1, and S'_3. In general for any support whose index is n, we have (Fig. 3)

Fig. 3.



on the left, the span l_{n-1}, on the right the span l_n; the shear infinitely near to n on the left is S'_{n-1}, on the right S_n; the sum of S'_{n-1}, and S_n makes the reaction R_n; and the moment over the support is M_n. If the load be uniform and equal to w per linear unit, the internal

shear S and moment M for any section x are given by

$$S = S_n - w x$$
$$M = M_n - S_n x + \tfrac{1}{2} w x^2$$

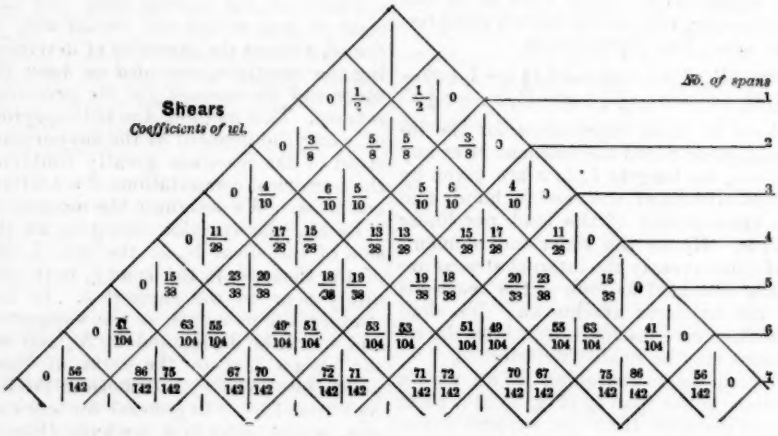
To find then the internal strains in the diagonals of a continuous truss due to dead load only, we have to pass a section cutting each diagonal and find the value of S, this is the shear which the strain in the diagonal must resist and multiplied by *sec.* θ (θ being the inclination of the diagonal to the vertical,) it gives the required strain. To find the strains in the upper chord we have to take the lower chord apices as centers of moments and compute the values of M; these divided by the depth of the truss give the strains, which are tensile if M is positive, compressive if M is negative. To find the lower chord strains, we choose the upper apices from which to measure the values of x, and divide the resulting values of M by the depth of the truss; if M is positive these give compressive strains; if negative, tensile ones.

Everything is thus known, except the shears and moments at the supports, and for these formulæ and methods will be presented in Chapter II, by which they may be found for all cases. We give here, however, two tables from which they may be found for the common case when all the spans are equal, and which, by a simple law, may be extended to include any number of such spans.

As before, let w be the uniformly distributed load per linear unit; let l be the length of each span, then will $w l$ be the weight of one span. The shear at any support is a fractional part of $w l$, or

$$\text{Shear} = \text{A}\, w l$$

A being a fraction given in the following triangle:

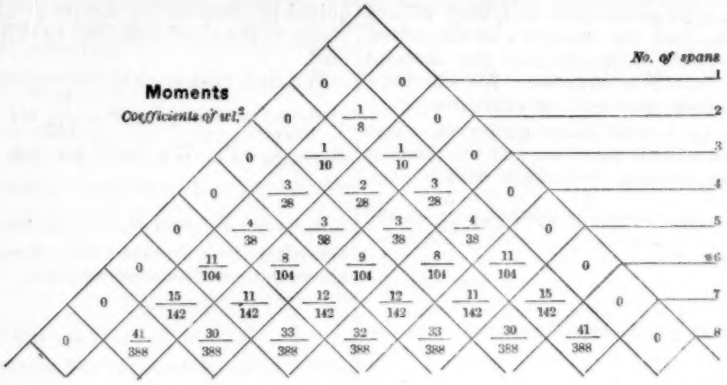


Each of the squares composing this triangle represents one of the supports, and its left hand division gives the left hand shear S'_{n-1}, and the right hand one the shear S_n (Fig. 3). Thus, in the girder of three spans, the triangle shows that the first support, beginning at the left, has on the left no shear, and on the right $\frac{4}{10}\, w l$, that the second support has on the left a shear of $\frac{6}{10}\, w l$, and on the right one of $\frac{5}{10}\, w l$. The sum of the two shears for any supports is of course its reaction. For example, a girder of six equal spans has at its middle support a reaction of $\frac{104}{104}\, w l$.

The moment at any support will be a fractional part of $w l$, or

$$\text{Moment} = \text{B}\, w l$$

B being a fraction given in the following triangle; in which like the preceding one the spaces indicate the supports of the girder. Thus, the fourth horizontal line refers to a girder of four spans, the moments at the first and last supports being 0, at the second and fourth $\frac{4}{71}\, w l^2$ and at the middle one $\frac{3}{71}\, w l^2$.



The triangles can be extended to any required length by the application of the following law which obtains in all *oblique* columns. Any fraction belonging to an *even* number of spans, may be obtained by multiplying both numerator and denominator of the preceding fraction by two and adding the numerator and denominator of the fraction preceding that. Thus for eight spans, the fraction $\frac{33}{388}$ is equal to $\frac{2\times 11+11}{2\times 142+104}$ or to $\frac{2\times 12+9}{2\times 142+104}$, according as we use one oblique column or the other. For an *odd* number of spans, any fraction is found by adding the two preceding fractions, numerator to numerator and denominator to denominator. Thus for seven spans,

$$\frac{12}{142}=\frac{8+4}{104+38} \text{ or } \frac{12}{142}=\frac{9+3}{104+38}.$$

These tables* furnish the data for solving all questions concerning continuous girders whose supports are on the same level, whose spans are all equal, and which are loaded uniformly throughout their entire length. The reader should first acquire facility in the use of the tables. We give, therefore, a few examples for practice:

1. In a girder of six spans, what is the reaction at the second support?

Ans. $R_2=\frac{118}{104}\,w\,l.$

2. In one of eight spans, what is the reaction at the middle support?

Ans. $R_5=\frac{386}{388}\,w\,l.$

3. In one of ten spans, what is the moment over the fourth support from the left?

Ans. $M_4=\frac{123}{1448}\,w\,l^2.$

4. In one of seven spans, what are the shears S_2 and S'_2? (see Fig. 3.)

Ans. $S_2=\frac{75}{142}\,w\,l \quad S'_2=\frac{67}{142}\,w\,l.$

5. In one of six spans, what is the moment M_6 and the shear S_6?

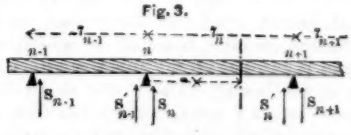
Ans. $M_6=\frac{11}{104}\,w\,l^2 \quad S_6=\frac{63}{104}\,w\,l^2.$

Having thus found from the triangles, the moment M_n and the shear S_n for the n^{th} support, the shear S and the moment M for any section in the n^{th} span are readily found from the formulæ

$$S=S_n-w\,x$$
$$M=M_n-S_n\,x+\tfrac{1}{2}\,w\,x^2$$

which we have demonstrated above, and

Fig. 3.



in which x is the distance from the support n to the assumed section. If in

* These triangles were first given by the author in the *Journal of the Franklin Institute* for March, 1875. A demonstration of the laws governing them may be seen in the same Journal for April, 1875.

these x be made equal to l, they will, of course, give the shear S'_n at the left of the $n+1^{th}$ support, and the moment M_{n+1} over that support. We will illustrate their use by a few examples :

6. In a continuous girder of three spans, what is the shear and the moment at the center of the middle span ?

We have from the table $S_2=\frac{5}{10}\,wl$ and $M_2=\frac{1}{10}\,wl^2$.

Hence

$$S=\frac{5}{10}\,wl-wx$$

$$M=\frac{1}{10}\,wl^2-\frac{5}{10}\,wlx+\tfrac{1}{2}\,wx^2$$

and placing x equal to $\frac{1}{2}\,l$, we have

$$S=0 \quad M=-\frac{1}{40}\,wl^2$$

7. In a girder of six spans, find the shear and moment at the center of the second span ?

Ans. $S=\frac{3}{104}\,wl \quad M=-\frac{7}{208}\,wl^2$

8. In one of four spans, what is the shear and moment in the third span for $x=\frac{1}{4}\,l$ and $x=\frac{3}{4}\,l$?

Ans. $S=\frac{3}{14}\,wl$ and $S=-\frac{4}{14}\,wl$

$M=\frac{7}{224}\,wl^2$ and $M=\frac{1}{224}\,wl^2$.

In computing a framed truss we need to find the value of S for a section cutting every diagonal and that of M for one passing through each panel apex. from these we readily derive the strains in the webbing and chords by the rules explained above. A single example will render the whole process clear. (We here treat of the dead load only ; computations involving the live or rolling load will be presented hereafter.)

Let the truss represented in Fig. 2 consist of seven continuous spans, each sixty feet in length. Let the uniformly distributed load per linear foot be two hundred pounds, one half of which rests upon the upper chord and the other half upon the lower. The lower chord is divided into six bays, each of ten feet, and is connected with the upper one by a Warren system of diagonals. The depth of the truss is seven feet. Let it be required to compute the strains in all the pieces of the third span, due to this dead load.

We first take from the triangles for a girder of seven spans, $S_2=\frac{70}{142}\,wl$ and $M_2=\frac{11}{142}\,wl^2$. We have for our case, $w=200$ lbs. and $l=60$ feet. Hence

$S_2=5916$ lbs. and $M_2=55775$ lbs. ft.

Inserting these and the value of w in the above general formulæ, we have

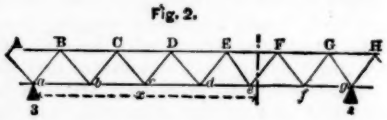
$$S=5916-wx$$

$$M=55775-5916\,x+100\,x^2$$

as the value of the shear and moment for any section x.

Now, since this is a framed truss, and the several pieces are to be subjected

Fig. 2.



only to longitudinal strains, the load should not be strictly uniformly distributed but concentrated on the upper chord at the panel points B, C, etc. and on the lower chord at a, b, c, etc. Allowing that each of these points receives an equal weight and that a and g, count as but one point, we have at a 500 lbs., at g 500 lbs. and at each of the others 1000 lbs. In finding the shear for the diagonal a B, we pass the section anywhere between a and B and take wx as 500, for B b wx is 1500, for b C 2500 and so on ; these subtracted from S_2 give the required shears. This is in fact nothing but taking the algebraic sum of all the exterior forces between the left hand of the truss and the diagonal under consideration, for S_2 is the sum of those forces from the left end to the beginning of the span. For the diagonal Fe we have, for example,

$$S = 5916 - 8500 = -2584 \text{ lbs.}$$

Thus by successive subtraction we find the shears for all diagonals. Multiplying them by the secant of the angle between a diagonal and the vertical or by

$$\text{Sec. } \theta=\frac{\sqrt{25+49}}{7}=1.229$$

and we have the required strains. To determine their character we have simply to consider that *a positive shear causes a* { *tensile* / *compressive* } *strain in a diagonal which slopes* { *upward* / *downward* } *toward the left hand support*, while a negative shear produces the reverse. In the following table, the results thus determined are recapitulated. The first column shows the name of the diagonal corresponding to Fig. 2, the second gives the shears, the third gives the slopes, + indicating an upward inclination toward the left, and — a downward one, and the last column gives the strains, + indicating *tension*, and — *compression*. In forming the last column from the two preceding ones, it will be noticed that the rule of signs is observed :

DIAGONALS. (See Fig. 2.)

Piece.	Shear.	Slope.	Strain.
B*a*	+5416	−	−6656 lbs.
B*b*	+4416	+	+5427
C*b*	+3416	−	−4198
C*c*	+2416	+	+2969
D*c*	+1416	−	−1740
D*d*	+ 416	+	+ 511
E*d*	− 584	−	+ 718
E*e*	−1584	+	−1947
F*e*	−2584	−	+3176
F*f*	−3584	+	−4405
G*f*	−4584	−	+5634
G*g*	−5584	+	−6863

We will now pass to the computation of the chord strains. In the above expression for M the quantity $\frac{1}{2} w x^2$ or $100 x^2$ is the moment of the load between the point 3 and the assumed section and its value is the same whether the load be considered as uniformly distributed or concentrated at the apices as above. Hence to find the moments for the upper chord we have in the expression

$$M = 55775 - 5916 x + 100 x^2$$

simply to give to x the successive values 0, 10, 20, etc., since for the bays A B, B C, C D, etc., the opposite vertices *a*, *b*, *c* etc., must be taken as centers of moments. Thus if the bay C D be cut rotation will at once begin around the point *c*; we take then $x = 20$ and find for the moment of the strain in C D,

$$M = -22545 \text{ lbs. ft.}$$

and dividing this by its lever arm or seven feet we have 3221 lbs for the strain. The character of the strain is found by recollecting that *a positive moment causes a* { *tensile* / *compressive* } *strain in the* { *upper* / *lower* } *chord*, while a negative moment produces the reverse. If we designate then tension by + and compression by −, the signs of the strains in the upper chord will be the same as those of the moments. In this way it is easy to compute the following results :

UPPER CHORD. (See Fig. 2).

Bay.	Moment.	Strain.
A B	+55775 lbs. ft.	+7968 lbs.
B C	+ 6615	+ 945
C D	−22545	−3221
D E	−31705	−4529
E F	−20865	−2981
F G	+ 9985	+1426
G H	+60845	+8692

For the lower chord the calculation is very similar. The centres of moments are taken at the points B, C, etc., the successive values of x are 5, 15, 25, etc., the strains are numerically one-seventh of the moments, and their signs are opposite to that of the moments. Thus for the bay *ef*, $x = 45$, M = − 7945 lbs. ft. and the strain in *ef* is 1135 lbs. tension. The results are in the following table :

LOWER CHORD. (See Fig. 2.)

Bay.	Moment.	Strain.
ab	+28695 lbs. ft.	−4099 lbs.
bc	−10465	+1495
cd	−29625	+4218
de	−28785	+4112
ef	− 7945	+1135
fg	+32895	−4699

and the strain sheet for the span is now complete.

In the same way the strains for each of the other spans may be readily found. From the symmetry of the truss it is evident that the fifth span will be exactly the same as the third, the sixth the same as the second, and the seventh the

same as the first. For the fourth span the value of S and M for any section x are

$$S = 6000 - w\,x$$
$$M = 60848 - 6000x + 100\,x^2$$

and the strains will be the same on each side of its center. For the first span S_1 is the same as the reaction R_1 the moment M_1 is zero and we have

$$S = 4732 - w\,x$$
$$M = -4732\,x + 100\,x^2$$

It will be seen then that the computation of the strains in a continuous girder is exactly the same as in a simple one, except only in the preliminary determination of the shears and moments at the supports. In a simple girder the end shears are the same as the reactions, which are known from the law of the lever, and the moments at the supports are zero. In a continuous one these quantities must be determined by formulæ, or, for the case of equal spans uniformly loaded,* taken from the triangles which we have given above. They may also be found by a graphical process.

If the truss above discussed were built with seven simple girders, the strains in each would be the same. It may prove interesting then to compare the results above found with those for a simple girder. The mode of computation is essentially the same ; the end shears are each one half the total load, the pieces A B and G H in Fig. 2 disappear, and for any section x we have

$$S = 6000 - w\,x$$
$$M = -6000x + 100x^2$$

Considering as before that the load is concentrated at the panel points we have 500 lbs. at a and g and 1000 lbs. at B, C, D, b, c, d, etc., respectively. We then find the shears and moments and from them deduce the strains as above described. The results are given below compared with those for the third span of the continuous truss.

(*See Table on following column.*)

Adding these strains regardless of sign we find the two sums to be the same. It can be easily demonstrated that for the dead load such should be

* Other convenient tables for concentrated loads and for uniform loads over one span only are given in the article above referred to in the *Journal of the Franklin Institute.*

DIAGONALS. (See Fig. 2.)

Piece.	Continuous truss.	Simple truss.
Ba	−6656 lbs.	−6760 lbs.
Bb	+5427	+5531
Cb	−4198	−4301
Cc	+2969	+3072
Dc	−1740	−1844
Dd	+ 511	+ 614
Ed	+ 718	+ 614
Ee	−1947	−1844
Fe	+3176	+3072
Ff	−4405	−4301
Gf	+5634	+5531
Gg	−6863	−6760
	Sums.... 44244 lbs.	44244 lbs.

the case. As far as the diagonals are concerned, the two structures require an equal amount of material.

UPPER CHORD. (See Fig. 2.)

Bay.	Continuous truss.	Simple truss.
A B	+7968 lbs.	
B C	+ 945	− 7143 lbs.
C D	−3221	−11429
D E	−4529	−12857
E F	−2981	−11429
F G	+1426	− 7143
G H	+8692	
	Sums.... 29762 lbs.	50001 lbs.

Adding the strains in the upper chord we observe that the sum for the simple truss is about 1.7 times that of the other. If the amount of material is to be proportional to the strain, a considerable saving will here be expected.

LOWER CHORD. (See Fig. 2.)

Bay.	Continuous truss.	Simple truss.
ab	−4099 lbs.	− 3929 lbs.
bc	+1495	− 9643
cd	+4218	−12500
de	+4112	−12500
ef	+1135	− 9643
fg	−4699	− 3929
	Sum.... 19758 lbs.	52144 lbs.

The lower chord in the simple truss

would then be subjected to about 2.6 times as much strain as in the continuous one.

If we suppose that the same working strength may be allowed for compression as for tension, we may obtain an estimate of the saving in material by employing a continuous truss instead of a simple one. The amount of material will be proportional to the strain and to the length of the piece strained. Regarding the bays of the chord as unity, the diagonals will be represented in length by 0.86. The proportionate amounts of iron will then be found by multiplying the above sums by unity for the chords and by 0.86 for the diagonals. Thus we have a

COMPARISON.

	Continuous truss.	Simple truss.
Diagonals	38050	38050
Upper Chord..	29762	50001
Lower Chord..	19758	52144
Total.....	87570	140195

from which we see that the amounts of material in the two cases are in the ratio of the numbers 87570 and 140195 or as 1 to 1.6. For this particular span then a saving in material of thirty-seven and a half per cent. is effected by using a continuous truss instead of a common one.

It is capable of demonstration that for girders subjected only to dead load, the total amount of strain in the webbing will be the same for simple as for continuous trusses, and also that under the most favorable circumstances, the total strain in the chords of the first is to that in the chords of the second as $\sqrt{27}$ is to 2 or nearly as 2.6 to 1.

In studying the theory of girders many interesting questions arise which are of little importance in practice. One of these is the determination of the inflection points. At these points the curvature of the beam changes, the strain passes from tension to compression and the moment is zero. At any point in the nth span the moment is

$$M = M_n - S_n x + \tfrac{1}{2} w x^2$$

Making in this M equal to zero and solving the equation with reference to x we find

$$x = \frac{S_n}{w} \pm \sqrt{\frac{S_n^2}{w^2} - \frac{2 M_n}{w}}$$

For a girder of equal spans and uniformly loaded we may hence write for the two inflection points,

$$x = A l \pm l \sqrt{A^2 - 2B}$$

in which A and B are to be taken from the above triangles, A always being taken for the right hand side of the support under consideration, for example, in a girder of eight spans the inflection points for the fourth span are at the points

$$x = \frac{195}{388} l \pm l \sqrt{\left(\frac{195}{388}\right)^2 - \frac{66}{388}}$$

or for $x = 0.22\ l$ and $x = 0.79\ l$.

The point of maximum moment, or the point near the center of the beam, where the chord strain is the greatest is more important and readily determined from the above general value for M. Differentiating it with reference to x we have

$$\frac{dM}{dx} = -S_n + w x = 0$$

that is, *the maximum moment obtains at the point where the shear is zero.* Its value is found by replacing x by $\frac{S_n}{w}$ which gives

$$\text{Max. } M = M_n - \frac{S_n^2}{2w}$$

as the greatest negative moment.

The following examples will enable the reader to test his knowledge of the preceding principles:

9. In a girder of two spans uniformly loaded what are the maximum positive and negative moments?

Ans. $0.125\ w l^2$ and $-0.071\ w l^2$.

10. In one of three spans what is the maximum negative moment in the middle span?

Ans. $-0.025\ w l^2$.

11. In one of eight spans where are the inflection points in the fifth span?

Ans. $x = 0.21\ l$ and $x = 0.78\ l$.

12. A continuous girder of three spans, each equal to fifty feet, is divided into five panels on the lower chord, and has

bracing similar to that shown in Fig. 2. Supposing a load of five tons applied at each of the lower panel points, what are the strains in each of the pieces of the middle span? the highest of the truss being six feet.

Ans. In $a\,b$, -11.7 tons; in $b\,c$, $+1.7$; in $B\,b$, $+13$; etc.

In this chapter we have treated of the continuous girder when affected only by dead load or its own weight. In the following chapters we shall take up the action of the live or variable load.

Chapter II.

A continuous girder, loaded in any manner, is held in equilibrium by the upward pressures or reactions of the supports, and, as we have seen, these reactions are alone sufficient for the complete determination of the strains in every part of the girder. But if, regarding the question as one of pure statics, we consider the beam as rigid, we find it impossible to determine the reactions when the number of supports is greater than two. This does not arise from the fact that in an actual case the question is indeterminate, but simply because in considering the girder as rigid we have restricted the data to the mere weight, neglecting entirely the physical properties of the material. By taking into account the *elasticity* of the girder, the problem becomes determinate; we find the reactions, or what is equivalent, the shears and moments at the supports, and from these the investigation of the internal forces or strains is easy.

THE ELASTIC LINE.

When a girder is acted upon by vertical forces, a change of shape arises, which causes the originally parallel fibers, to be on one side lengthened, and on the other shortened. Between the lengthened and shortened fibers, there is a plane which undergoes no change of length; the central line of this plane is called the *neutral axis* or the *elastic line*. Thus, in the bent beam represented in Fig. 4, $m\,o$ is the neutral axis, the fibers above it being shortened or compressed, and those below it lengthened or tensioned.

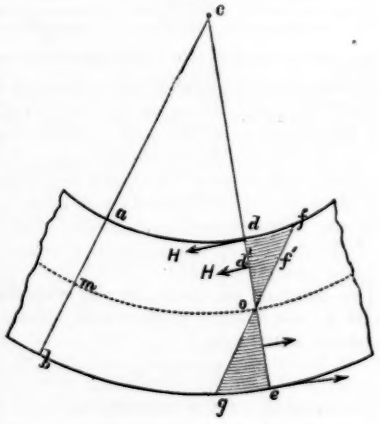
We derive the equation of the elastic line upon three hypotheses: 1*st*, that all planes perpendicular to the neutral axis before the bending or flexure, preserve during the bending their perpendicularity and their form as planes; 2*d*, that the change of length of a body subjected to a force is, within certain limits called the elastic limits, proportional to the intensity of the force; and 3*d*, that the change of shape is so little that the length of the neutral axis is sensibly the same as its horizontal projection.

In Fig. 4 we have a longitudinal section of a portion of a bent beam; the two planes $a\,b$ and $d\,e$, originally parallel, remaining perpendicular to the neutral axis $m\,o$, and intersecting in c the center of curvature. Hence, drawing $f\,g$ parallel to $a\,b$ through o, the lines $f\,d$, $g\,e$, etc., denote the elongations and compressions of the respective fibers, and we see from the figure that

$$o\,d : o\,d' :: d\,f : d'\,f'$$

or the change of length in the fibers is proportional to their distances from the neutral axis. This is the consquence of the first hypothesis.

Fig. 4.



Designating by H and H′ the forces acting in the fibers $d\,f$ and $d'\,f'$, the second hypothesis says that

$$H : H' :: d\,f : d'\,f'$$

Hence, by combining these two proportions,

$$H : H' :: o\,d : o\,d'$$

or, the horizontal forces are directly proportional to their distances from the neutral axis. Therefore, if we denote the distance of *any* fiber from the axis

by z the strain upon it by H′, the distance of the remotest fiber by e and the strain upon it by H, we have

$$H' : H :: z : e \quad \text{or } H' = \frac{H z}{e}$$

We have thus far considered the cross-section of the fibers as unity. If the actual section be a, the force in each is evidently $\frac{H a z}{e}$. Each of these forces, as for instance H′ in the figure, tends to turn the beam around the point o with a lever arm $o d'$ or z, and its moment or the measure of that tendency to rotation is the product of the force $\frac{H a z}{e}$ by the distance z, or $\frac{H a z^2}{e}$. The sum of all these moments is

$$M = \frac{H}{e} \Sigma a z^2$$

or, since $\Sigma a z^2$ is the moment of inertia of the section $a b$, we have

$$M = \frac{H I}{e}$$

as the expression for the sum of the moments of the internal forces, H being the strain in the remotest fiber, e its distance from the neutral axis, and I the moment of inertia of the cross-section.

The line $d f$ denotes the change of length of the fiber $a d$ due to the force H. Hence if E be the coefficient of elasticity,*

$$a d : d f :: E : H$$

Designating the radius $c o$ by r we have from the similar figures $o d f$ and $c a d$ (since $m o = a d$),

$$a d : d f :: r : e$$

Combining these proportions we find

$$\frac{H}{e} = \frac{E}{r}$$

and hence, for the value of the internal moment, we have

$$M = \frac{E I}{r}$$

* The *Coefficient of Elasticity* is the ratio of the force of displacement to the amount of displacement taken upon a cube whose edge is unity; Hence for the above case $E = H \div \frac{d f}{a d}$. The term modulus of elasticity properly relates to the impact of bodies, and is a measure of elasticity in the common sense of the word, unity indicating perfect elasticity or restitution of form. These terms are often confounded by writers.

The radius of curvature of any plane curve, whose length is u, and co-ordinates x and y is*

$$r = \frac{d u^3}{d x\, d^2 y}$$

And as by our third hypothesis we may place $d u = d x$, this becomes

$$r = \frac{d x^3}{d^2 y}$$

which, inserted in the above value of M, gives

$$(1) \qquad \frac{d^2 y}{d x^2} = \frac{M}{E I}$$

as the differential equation of the elastic curve, applicable to all bodies subject to flexure, which fulfill the condition imposed by the third hypothesis. The coefficient of elasticity and the moment of inertia may be different in every section.

CONDITIONS OF EQUILIBRIUM.

Let us consider the r^{th} span of a continuous girder whose length is l_r, and let a single concentrated load P_r be placed on this span at a distance $k l_r$ from the left hand support r. This load, the loads on the other spans, and the weight of the girder itself, are held in equilibrium by the vertical reactions R_{r-1}, R_r, etc., of the several supports.

Let us pass a section between the load P_r and the support $r+1$ at a distance x from the r^{th} support. As shown in the last chapter, all the internal forces in this section are represented by a shear S and a moment M. The shear S is equal to the algebraic sum of all the external forces upon the left hand side of the section, and the moment M is equal to the sum of the moments of those forces with respect to the section as a center. Hence, regarding upward forces as positive, and a moment as positive when it tends to cause tension in the upper fiber of the section, we have

$$(2) \qquad \begin{aligned} S &= S_r - P_r \\ M &= M_r - S_r x + P_r (x - k l_r) \end{aligned}$$

in which S_r is the shear at the right of the r^{th} support, and M_r the moment at that support. In like manner for a section between r and P_r, we have

$$\begin{aligned} S &= S_r \\ M &= M_r - S_r x \end{aligned}$$

* See any work on the Differential Calculus.

The internal forces at any section can then be found as soon as the shear and moment at the preceding support are known.

If, in the above expression, we make x equal to l_r, M becomes M_{r+1}, and we deduce

$$(3)\quad S_r = \frac{M_r - M_{r+1}}{l_r} + P_r\,(1-k)$$

The shear and moment at any section can then be determined as soon as M_r and M_{r+1}, the moments at the preceding and following supports, are known.

These conditions of equilibrium are entirely independent of variations in the dimensions or material of the beam, or in the relative heights of the supports of the girder.

THE EQUATION OF THE ELASTIC LINE.

In order to apply equation (1) to the case of continuous girders, we have to insert for M, E and I their values as functions of x and integrate the equation twice. E, however, cannot under any ordinary circumstances be a function of x, it being dependent upon the elasticity of the material alone, which is nearly the same in one and the same beam, and we hence regard it as constant. In a beam of uniform section I is constant, and although it varies in common bridge trusses, we shall be obliged in order to bring the investigation within the limits of this paper to consider it always as constant, taking care to point out afterwards the slight error thus introduced. Inserting then in (1) the value of M from (2), we have

$$\frac{d^2y}{dx^2} = \frac{M_r - S_r x + P_r\,(x-k\,l_r)}{E\,I}$$

as the differential equation, applicable to girders of constant elasticity and uniform cross section. Integrating this, the constant is t_r, the tangent of the inclination of the elastic line at the support r and

$$(4)\quad \frac{dy}{dx} = t_r + \frac{2\,M_r x - S_r x^2 + P_r\,(x-k\,l_r)^2}{2\,E\,I}$$

we have thus far taken no account of the relative heights of the supports. For the reasons mentioned in the last chapter, we shall consider them as all upon the same level. The constant for the second integration is then 0, the origin being at r, and we have

$$(5)\quad y = t_r\,x + \frac{3\,M_r x^2 - S_r x^3 + P_r(x-k\,l_r)^3}{E\,I}$$

as the equation of the elastic curve between the load P_r and $r+1^{th}$ support (Fig 5). If there be several loads we have only to affix the sign of summation Σ to the term involving P_r, and if that term be omitted we shall have the equation between the load and the r^{th} support, since for any section between those points $M = M_r - S_r x$.

If in (5) we make $x = l_r$, y becomes 0, and inserting for S_r its value from (3), we find

$$(6)\quad 6\,E\,I\,t_r = -2\,M_r\,l_r - M_{r+1}\,l_r + P_r\,l_r^2\,(2\,k - 3\,k^2 + k^3)$$

Thus the equation of the curve is completely determined, when we know M_r and M_{r+1} the moments at the supports r and $r+1$. These may be found by the remarkable theorem of three moments.

THE THEOREM OF THREE MOMENTS.

In Fig. 5 is represented a portion of a continuous truss. Beginning at the left hand end, the lengths of the spans are denoted by $l_1, l_2, \ldots l_r$ etc., and the supports are designated as 1, 2, ... r, etc. Upon the spans l_{r-1} and l_r are loads P_{r-1} and P_r, whose distances from the nearest left hand supports are $k\,l_{r-1}$ and $k\,l_r$, k being any fraction less than unity, and not necessarily the same in the two cases. The equation of the elastic line between P_r and the support $r+1$ is given by (5), and the tangent of the angle which the curve at the section x makes with the axis of abscissæ is given by (4).

FIG. 5.

If in (4) we substitute for S_r its value from (3), and for t_r its value from (6), and make $x = l_r$, $\frac{dy}{dx}$ becomes t_{r+1} the tangent of the inclination of the curve at $r+1$, and we find

$$6\,E\,I\,t_{r+1} = M_r\,l_r + 2\,M_{r+1}\,l_r - P_r\,l_r^2(k-k^3)$$

Now, if we consider the origin moved from the support r back to $r-1$, we may

derive a value for t_r by simply diminishing each of the indices in the above expression by unity, hence

$$(7)\quad 6\,E\,I\,t_r = M_{r-1}\,l_{r-1} + 2\,M_r\,l_{r-1} - P_{r-1}\,l'_{r-1}\,(k-k^3)$$

Equating the values of $6\,E\,I\,t_r$ given by (6) and (7), we have

$$(8)\quad M_{r-1}\,l_{r-1} + 2\,M_r(l_{r-1}+l_r) + M_{r+1}\,l_r = P_{r-1}\,l'_{r-1}\,(k-k^3) + P_r\,l'_r(2\,k-3k^2+k^3)$$

which is the most general form of the theorem of Three Moments for girders of constant cross-section. By prefixing the sign Σ to the terms in the second member, it becomes applicable to any number of single loads. For uniform loads w_{r-1} and w_r per linear unit, we have only to place

$$P_{r-1} = w_{r-1}\,d\,(k\,l_{r-1}) = w_{r-1}\,l_{r-1}\,d\,k$$
$$P_r = w_r\,d\,(k\,l_r) = w_r\,l_r\,d\,k$$

And to replace the sign of summation Σ by that of integration $\int$. If these loads extend over the entire spans l_r and l_{r-1}, we take the integrals between the limits $k=0$ and $k=1$, and have

$$M_{r-1}\,l_{r-1} + 2\,M_r\,(l_r + l_{r-1}) + M_{r+1}\,l_r = \frac{w_{r-1}\,l'_{r-1}}{4} + \frac{w_r\,l'_r}{4}$$

which is the theorem as first announced by Clapyron.

For each support of a continuous girder an equation may be therefore written involving the moment at that support, and those at the preceding and following support. In a girder of s spans there are $s+1$ supports, and since the moments at the first and last supports are zero we have $s-1$ moments, whose values may be found by the solution of the $s-1$ equations. The moments give the shear at any support, and by (2) the internal forces or strains may be determined for every section of the girder.

REMARKS ON THE PRECEDING THEORY.

The laws of the theory of continuity above deduced can be regarded as only approximate. Of the three hypotheses upon which the differential equation of the elastic line is deduced, the first, although a most reasonable assumption, has not been definitely verified by experiment, and the second is rendered somewhat doubtful by the extreme difficulty in delicate experiments of assigning the elastic limits. Nevertheless they are universally regarded by all writers as sufficiently accurate to form the basis of a working theory, and must continue to be thus used until we attain to a more thorough knowledge of matter and force. The third hypothesis, however, is a limitation of the data, which we are at perfect liberty to make, since we know that the increase in length of the girder by deflection is too small to be practically measured. We may conclude then that the equation (1) is an extremely close approximation to the actual law governing straight elastic beams. From the time of Navier to the present it has been so accepted and used.

The next hypothesis or limitation of data, which we make, is that E, the coefficient of elasticity, is constant throughout the girder. In a solid beam of ordinary homogeneous material, there can be no reason for supposing it otherwise.

In the *Journal of the American Society of Civil Engineers* for May, 1876, appeared an article by Charles Bender, C. E., in which the use of continuous bridges is strongly opposed. One of his main objections is—that the theory upon which such bridges are computed is unreliable in consequence of the assumption of a constant coefficient of elasticity, and he quotes the records of experimenters to show that values for the coefficient of iron and steel have been observed ranging from 17,000,000 to 40,000,000 pounds per square inch. These limiting values are, however, decidedly exceptional, but even granting that such variations may exist in materials and forms like soft iron wire, steel rails and wrought iron eye-bars, it cannot be supposed that they will occur in one and the same structure, where the material is of one kind, of similar cross sections and which has been subjected in the same mill to the same process of manufacture. The mere statement that Morin has observed values of the coefficient of elasticity as low as 17,000,000 has very little weight when unaccompanied by any reference to the kind of iron experimented upon. Let us see what Morin himself actually says

in recapitulating the results of experiments upon wrought iron.*

"Iron of *superior quality*, which comes from standard ores, and which has been manufactured exclusively with charcoal, or iron from sheet metal, many times refined, may give for the coefficient of elasticity values as high as E=28,400,000, or even E=31,200,000 lbs. per square inch, equal to those furnished by ordinary steel. Iron of *ordinary* manufacture reduced with common coal, and drawn into forms like rails, T irons, flanges, etc., give such values as E = 24,100,000 and E = 25,600,000. Finally the *most soft and ductile* iron furnishes values as low as E=21,300,000, or E=19,800,000, or even E=17,000,000. It is well, then, in calculations upon the strength of iron, to ascertain the quality of the material and the process of manufacture."

Mr. Bender likewise alludes to experiments upon wrought iron bars in which the coefficient of elasticity was found to be 40,000,000, and it seems to be implied by his language that such values are of common occurrence. The fact, however, that a standard writer on the strength of materials, like Morin, regards 34,000,000 as an exceptionally high figure for iron, may justify us in demanding that when a value like 40,000,000 is quoted, we should be furnished with some details concerning the quality of such iron, the process of manufacture, as well as a description of the testing machine and the manner of measuring the small extensions or compressions, from which the coefficient is calculated, or at least that we should be referred to the book or journal where such experiments are described. And further as it is well known that by straining a bar beyond the elastic limits, very low values of E can be deduced, are we not justified in asking similar information concerning experiments which furnish such values?

Undoubtedly there is some variation in the elasticity of different pieces of iron, even when great care has been taken to ensure uniformity of material and manufacture, and it is greatly to be desired that experiments should be made to determine how it varies with the cross section and length of the piece. As soon as such a law of variation is discovered (if any exist), we shall be obliged to consider E as variable in investigating a continuous truss. But if no law exists and we know only the fact that there are slight variations in the elasticity of different pieces in the same truss, what is to be done? Nothing but to regard E as constant, being well assured that the distribution of the variable pieces throughout the structure will be governed by the law of probability, and that hence the girder as a whole will conform closely to the theoretic form of the elastic line.

The next argument which it is our duty to criticise in that article is, that the theory of continuous girders is unreliable, because the calculated deflection does not generally agree with the actually measured deflection. The accuracy of the computed strains must depend upon the accuracy of the theorem of three moments, and this it is asserted depends upon the calculated deflection. And because the deflection as actually measured is sometimes no more than one-half of the calculated one, hence, it is said, the same differences may occur in the strains, and the whole theory is unworthy of consideration.

This we can only regard as a striking instance of the incompetency of practical men to draw conclusions from even simple experiments. The reader who has followed onr presentation of the theory of the elastic line, will see at once that the value of the deflection given by (5) only enters the discussion as an auxiliary for finding (6), the tangent of the inclination angle at the support. The process supposes, indeed, that E is constant, but it supposes nothing whatever concerning the value of the deflection at any point. When we pass to the next span and find again in (7) a second value of the tangent, the actual value of the deflection there is likewise not considered. And when by the combination of (6) and (7), we deduce (8) in which E does not appear, its very absence is a proof that the moments and hence the strains are entirely independent of its value or of the actual deflection. If two trusses of the same spans, height and form are continuous over several supports, one of steel hav-

*Morin; *Resistance des Materiaux*, Paris, 1862. Vol. I, p. 443.

ing a coefficient of elasticity of 31,000,000 lbs. per square inch, and the other of wood having a coefficient of only one-twentieth as much, the reactions, shears, moments and strains would be the same in each. The measurement of the actual deflections of these bridges under given loads is only useful for determining and comparing their stiffness or elasticity, or in connection with theory for finding the values of E and I. The theory of continuity rests not upon absolute deflections, but on relative ones—on the *form* of the elastic curve, and this again upon the three universally accepted hypotheses included in our equation (1), with the additional assumption that the coefficient of elasticity is practically constant.

One more remark and we close for to-day a discussion which shall be resumed in our next chapter. Mr. Bender advises us to abandon the theory of flexure, to make no further advance in bridge building, to remain content with the simple lever, or at the utmost with the continuous (*sic*) patent hinged truss. But until such advice is enforced by more logical arguments than we have yet seen, we "young theorists" must continue our work in support of a theory and system which is universally accepted as only slightly deviating from the exact existing conditions, which is applied in the erection of continuous bridges by every nation except our own, and which perhaps if carried out by us might lead to more perfect structures than the world has yet seen. The great majority of coefficients of elasticity quoted in his paper, made by such men as Staudinger, Baker, Morin and Wöhler, were in fact *found by measuring the deflections of beams, and then from the theory of flexure computing the value of* E. He accepts those values, and on their evidence condemns the theory by which they were deduced! Is not Morin's conclusion, which we have quoted above, by far the most reasonable?

THE ART OF MEASURING.*

By Dr. C. W. SIEMENS.

From "Engineering."

Regarding the question of measurement, this constitutes perhaps the largest and most varied subject in connection with the present Loan Exhibition. In mechanical science, accurate measurement is of such obvious importance, that no argument is needed to recommend the subject to your careful consideration. But it is not perhaps so generally admitted, that accurate measurement occupies a very important position with regard to science itself, and that many of the most brilliant discoveries may be traced back to the mechanical art of measuring. In support of this view I may here quote some pregnant remarks made by Sir William Thompson in his inaugural address, delivered in 1871 to the members of the British Association, in which he says, "Accurate and minute measurement seems to the non-scientific imagination, a less lofty and dignified work than looking for something new. But nearly all the grandest discoveries of science have been but the rewards of accurate measurement and patient long-continued labor in the minute sifting of numerical results. The popular idea of Newton's grand discovery is that the theory of gravitation flashed upon his mind, and so the discovery was made. It was by a long train of mathematical calculation, founded on results accumulated through prodigious toil of practical astronomers that Newton first demonstrated the forces urging the planets towards the sun, determined the magnitude of those forces, and discovered that a force following the same law of variation with distance urges the moon towards the earth. Then first, we may suppose, came to him the idea of the *universality*

* Abstract of a report of the opening address delivered by Dr. C. W. Siemens at the Mechanical Section of the Conferences in connection with the Exhibition of Scientific Apparatus at South Kensington.

of gravitation; but when he attempted to compare the magnitude of the force on the moon with the magnitude of the force of gravitation of a heavy body of equal mass at the earth's surface, he did not find the agreement which the law he was discovering required. Not for years after would he publish his discovery as made. It is recounted that, being present at a meeting of the Royal Society, he heard a paper read, describing geodesic measurement by Picard, which led to a serious correction of the previously accepted estimate of the earth's radius. This was what Newton required; he went home with the result, and commenced his calculations, but felt so much agitated, that he handed over the arithmetical work to a friend; then (and not when sitting in a garden he saw an apple fall) did he ascertain that gravitation keeps the moon in her orbit.

"Faraday's discovery of specific inductive capacity, which inaugurated the new philosophy, tending to discard action at a distance, was the result of minute and accurate measurement of electric forces.

"Joule's discovery of thermo-dynamic law, through the regions of electro-chemistry, electro-magnetism, and elasticity of gases was based on a delicacy of thermometry which seemed impossible to some of the most distinguished chemists of the day.

"Andrews' discovery of the continuity between the gaseous and liquid states was worked out by many years of laborious and minute measurement of phenomena scarcely sensible to the naked eye."

Here, then, we have a very full recognition of the importance of accurate measurement, by one who has a perfect right to speak authoritatively on such a subject. It may indeed be maintained that no accurate knowledge of anything or any law in nature is possible, unless we possess a faculty of referring our results to some unit of measure, and that it might truly be said—*to know is to measure.*

To resort to a homely illustration of this proposition, let us suppose a traveler in the unknown wilds of the interior of Africa observing before him a number of elevations of the ground, not differing materially from one another in apparent magnitude. Without measuring apparatus the traveler could form no conclusion regarding the geographical importance of those visible objects, which might be mere hillocks at a moderate distance, or the domes of an elevated mountain range. In stepping his base line, however, and mounting his distance-measurer he soon ascertains his distances, and observations with the sextant and compass give the angles of elevation and position of the objects. He now knows that a mighty mountain chain stands before him, which must determine the direction of the watercourses and important climatic results. In short, through measurement he has achieved perhaps an important addition to our geographical knowledge. As regards modern astronomy, this may almost be defined as the art of measuring very distant objects, and this art has progressed proportionately with the perfection attained in the telescopes and recording instruments employed in its pursuit.

By the ancients the art of measuring length and volume was tolerably well understood, hence their relatively extraordinary advance in architecture and the plastic arts. We hear also of powerful mechanical contrivances which Archimedes employed for lifting and hurling heavy masses; and the books of Euclid constitute a lasting proof of their powers of grappling with the laws regulating the proportion of plane and linear measurement. But with all the mental and mechanical power displayed in those works, it would seem strange that no attempt should have been made on the part of the ancients to utilize those subtle forces in nature, *heat* and *electricity*, by which modern civilization has been distinguished, were it not for their want of means of *measuring* these forces.

Hero, of Alexandria, tells us that the power of steam was known to the Egyptians, and was employed by their priesthood to work such pretended miracles as that of the spontaneous opening of the doors of the temple whenever the burnt offering was accepted by the gods, or, as we moderns would put it, whenever the heat generated by combustion was sufficient to produce steam in the hollow body of the altar, and thus force water into buckets whose increasing weight, in descending, caused the gates in question to open.

Unfortunately for them, the Academia de Cimento of Florence had not yet presented the world with the thermometer, nor had Toricelli shown how to measure elastic pressures, or there would, at any rate, have been a probability of those clear-headed ancients applying the power of steam for preparing and transporting the materials which they used in the erection of their stupendous monuments, and for raising and directing the water used in their elaborate works of irrigation.

The art of measuring may be divided into the following principal groups :

1st. That of linear measurement, the measurement of area within a plane, and of plain angles ; comprising geometry, trigonometry, surveying, and the construction of linear measures, distance meters, sextants, and planimeters, of which a great variety will be found within this building.

The subject of linear measurement will, I am happy to state, be brought before you by one whose name will ever be remembered as the introducer into applied mechanics of the absolute plane, and of accurate measure, I mean Sir Joseph Whitworth. It is to be regretted, I consider, that Sir Joseph Whitworth adopted as the unit of measure, the decimalized inch, instead of employing the centimeter, and I hope that he will see reason to adapt his admiral system of gauges, also to metrical measure, which, notwithstanding any objections that could be raised against it on theoretical grounds—that, namely, of not representing accurately the ten millionth part of the distance from one of the earth's poles to its equator—is, nevertheless, the only measure that has been thoroughly decimalized, and which establishes a simple relationship between measures of length, of area, and of capacity. It possesses, moreover, the great practical advantage of having been adopted by nearly all the civilized nations of Europe, and by scientific workers throughout the world. Sir Joseph Whitworth's gauges, based upon the decimalized inch, are calculated to maintain their position for many years, owing to the intrinsic mechanical perfection which they represent, but the boon conferred by their author would be still greater than it is, if, by adopting the meter he would remove the last and only serious impediment in the way of the unification of linear measurement throughout the world. A discussion will probably arise regarding the relative merits of measurement *a bout*, of which Sir Joseph Whitworth is the representative, and of measurement *a trait*, which is the older method, but is still maintained by the Standard Commissioners, both in this country and in France.

The second group includes the measure of volume or the cubical contents of solids, liquids, and gases, comprising stereometric methods of measurement, the standard measures of liquids, and the apparatus for measuring liquid and gaseous bodies flowing through pipes, such as gas meters, water meters, spirit meters, of which, likewise, a great variety of ancient and modern date will meet your eye, and upon which Mr. Merrifield will address you.

Another method of measuring matter is by its attraction towards the earth, or, thirdly, the measurement of weight, represented by a great variety of balances of ancient and modern construction. These may be divided into *beam weighing machines* (which appear to be at the same time the most ancient and the most accurate), into spring balances and torsion balances. The accuracy obtained in weighing is truly surprising, when we see that a mass of one ten-millionth part of a gramme suffices to turn the scale of a well-constructed chemical balance. Perfect weighing, however, could only be accomplished in a vacuum, and, in accurate weighing, allowance has to be made for the weight of air displaced by the object under consideration. The general result is that the mass of light substances is really greater than their nominal weight implies, and this difference between true and nominal weight must vary sensibly with varying atmospheric density.

Weighing in a denser medium than atmospheric air, namely, in water, leads us, fourthly, to the measurement of specific gravity, which was originated by Archimedes when he determined the composition of King Hiero's crown by weighing it in water and in air.

Among measures of weight may be noted a balance, which weighs to the

five-millionth part of the body weighed, sent by Beckers Sons, of Rotterdam; another from Brussels, weighing to within a fourteen-millionth part of the weight, in weighing small quantities; a balance formerly used by Dr. Priestly; and Professor Hennessy's standards, derived from the earth's polar axis, as common to all terrestrial meridians.

Next comes, fifthly, the *Measurement of Time*, which, although of ancient conception, has been reduced to mathematical precision only in modern times. This has taken place through the discovery by Galileo of the pendulum, and its application, by Huygens, to timepieces in the seventeenth century. The most interesting exhibits in this branch of measurement are, from an historical point of view, the Italian, German, and English clocks of the seventeenth century; the timekeeper which was twice carried out by Captain Cook, first in 1776, and which, after passing through a number of hands, was brought back to this country in 1843; and an ancient striking clock supposed to have been made in 1348—it has the verge escapement, which is said to have been in use before the pendulum. The methods employed in modern clocks and watches for compensating for variation of the thermometer and barometer, are illustrated by numerous exhibits, notably the astronomical clock, with Sir George Airy's compensation, which will form the subject of a special demonstration by Messrs. Dent and Co.

The measurement of small increments of time has been rendered possible only in our own days by the introduction of the conical pendulum, and other apparatus of uniform rotation, which alone convey to our minds the true conception of the continuity of time. Among the exhibits belonging to this class must be mentioned Sir Charles Wheatstone's rotating mirror, moved by a constant falling weight, by which he made his early determination of the velocity of electricity through metallic conductors; the rotative cylindrical mirror, marked by successive electrical discharges, which was employed by Dr. Werner Siemens in 1846, to measure the velocity of projectiles, and has been lately applied by him for the measurement of the velocity of the electric current itself, and the chronometric governor, introduced by him in conjunction with myself, for regulating chronographs, as also the velocity of steam engines under their varying loads; Foucault's governor, and a considerable variety involving similar principles of action.

Another entity which presents itself for measurement is, sixthly, that of *Velocity*, or distance traversed in a unit of time, which may either be uniform or once influenced by a continuance of the cause of motion, resulting in acceleration, subject to laws and measurements applicable both in relation to celestial and terrestrial bodies. I may here mention the instruments latterly devised for measuring the acceleration of a cannon ball before and after leaving the mouth of the gun, of which an early example has been placed within these galleries. Other measures of velocity are to be found here, ships' logs, current meters, and anemometers.

In combining the ideas of weight or pressure with space we arrive at, seventhly, the conception of work, the unit of which is the foot-pound or kilogrammeter, and which, when combined with time, leads us to the further conception of the performance of duty, the horse-power, as defined by Watt. The machines for the measurement of work, here exhibited, are not numerous, but are interesting. Among these may be mentioned Prof. Colladon's dynamometrical apparatus, constructed in 1844; Richard's patent steam engine indicator, an improvement on Watt's, and Mr. G. A. Hirn's flexion and torsion pandynamometers.

Eighth. The measurement of *Electrical Units*—of electrical capacity of potential—and resistance, forms a subject of vast research, and of practical importance, such as few men are capable of doing justice to. It may be questioned, indeed, whether electrical measurement belongs to the province of mechanical science, involving, as it does, problems in physical science of the highest order: but it may be contended, on the other hand, that at least one branch of applied science, that of telegraphy, could not be carried on without its aid. I am happy to say that this branch of the general subject will be brought before you by my esteemed friend Sir William Thomson, than whom there is no one more

eminently qualified to deal with it. I may, therefore, pass on to the next great branch of our general subject, the ninth: *Thermal Measurement.*—The principal instrument here employed is the thermometer, based in its construction either upon the difference of expansion between two solids or on the expansion of fluids such as mercury or alcohol (the common thermometer), or upon gaseous expansion (the air thermometer); or again, it may be based upon certain changes of electrical resistance which solids and liquids experience when subjected to various intensities of heat. With reference to these, the air thermometer represents most completely the molecular action of matter which is the equivalent of the expansibility. I shall not speak of the different scales that have been adopted by Réaumur, Celsius, and Fahrenheit, which are based upon no natural laws or zero points in nature, and which are therefore equally objectionable upon theoretical grounds. Would it not be possible to substitute for these a natural thermometric scale?—one commencing from the absolute zero, of the possible existence of which we have many irrefutable proofs, although we may never be able to reach it by actual experiment. A scale commencing in numeration from this hypothetical point would possess the advantage of being in unison throughout with the physical effects due to the nominal degree, and would aid us in appreciating correctly the relative dynamical value of any two degrees of heat which could be named. Such a scale would also fall in with the readings of an electrical resistance thermometer or pyrometer, of which a specimen has been added to this collection by myself.

When temperature or intensity of heat is coupled with mass we obtain the conception of quantity of heat, and if this again is referred to a standard material, usually water, the unit weight of each being taken, we obtain what is known as specific heat. The standard to which measurements of quantity of heat are usually referred is the heat required to raise a pound of water one degree Fahrenheit, or the cubic centimeter of water one degree Centigrade.

The most interesting exhibits in this branch of measurement are, from an historical point of view, the original spirit thermometer of the Florentine Academia del Cimento, and the photographs of old thermometers; the original Lavoisier calorimeter for measuring the heat disengaged in combustion; Wedgwood's and Daniell's pyrometers.

As illustrating modern improvement, may be instanced a long brass-cased thermometer showing the variations in the readings when the bulb and when the whole thermometer is immersed; a thermometer with flat bulb to improve sensitiveness; a thermo-electric alarum, for giving notice when a given temperature is reached; an instrument for measuring the temperature of fusion by means of electric contact, invented by Professor Himly; Dr. Andrews' apparatus for measuring the quantity of heat disengaged in combustion; Dr. Guthrie's diacalorimeter for measuring the conductivity of liquids for heat, and a thermometric tube by Professor Wartmann for determining the calorific capacities of different liquids by the process of cooling.

Finally, Joule has taught us how to measure the unit of heat dynamically, and the interesting apparatus employed by him from time to time in the various stages of the determination of this most important constant in applied mechanics, are to be found, rightly placed, not among thermometers and other instruments placed in the physical sections, but among the instruments required in the determination of three great natural standards—of length, time, and mass, and their combinations.

Another branch of the general subject is the *Measurement of Light*, which may be divided into two principal sections, that including the measurement of the wave-length of light, of different colors, and the angle of polarization, which belongs purely and entirely to physical science; and the measurement of the intensity of light by photometry, which, while involving also physical problems of the highest order, has an important bearing also upon applied science. The principal methods that have been hitherto employed in photometry are by the comparison of shadows—that of Rumford and Bouguer; by employing a screen of paper with a grease-spot, the lights to be compared being so adjusted that the spot does not differ in appearence from

the rest of the paper—Bunsen's method; Elster's, by determining in combustion the amount of carbon contained in a given volume of a gas; and the one lately introduced by Professor Adams and Dr. Werner Siemens, by measuring the variation in the electrical resistance of selenium, under varying intensities of light.

Before concluding, I wish to call your attention to two measuring instruments which do not fall within the range of any of the divisions before indicated. The first is an apparatus designed chiefly by my brother, Dr. Werner Siemens, by which a stream composed of alcohol and water, mixed in any proportion, is measured in such a manner that one train of counter wheels records the volume of the mixed liquid; whilst a second counter gives a true record of the amount of absolute alcohol contained in it. The principle upon which this measuring apparatus acts may be shortly described thus:—The volume of liquid is passed through a revolving drum, divided into three compartments by radial divisions, and not dissimilar in appearance to an ordinary wet gas-meter; the revolutions of this drum produce the record of the total volume of passing liquid. The liquid on its way to the measuring drum passes through a receiver containing a float of thin metal filled with proof spirit, which float is partially supported by means of a carefully-adjusted spring, and its position determines that of a lever, the angular position of which causes the alcohol counter to rotate more or less for every revolution of the measuring drum. Thus, if water only passes through the apparatus the lever in question stands at its lowest position, when the rotative motion of the drum will not be communicated to the alcohol counter, but in proportion as the lever ascends a greater proportion of the motion of the drum will be communicated to the alcohol counter, and this motion is rendered strictly proportionate to the alcohol contained in the liquid, allowance being made in the instrument for the change of volume due to chemical affinity between two liquids. Several thousand instruments of this description are employed by the Russian Government in controlling the production of spirits in that empire, whereby a large staff of officials is saved, and a perfectly just and technically unobjectionable method is established for levying the excise dues.

Another instrument, not belonging to any of the classes enumerated, is one for measuring the depth of the sea without a sounding line, which has recently been designed by me, and described in a paper communicated to the Royal Society. Advantage is taken in the construction of this instrument of certain variations in the total attraction of the earth, which must be attributable to a depth of water intervening between the instrument and the solid constituents of the earth. It can be proved mathematically that the total gravitation of the earth diminishes proportionately with the depth of water, and that if an instrument could be devised to indicate such minute changes in the total attraction upon a scale, the equal divisions on that scale would represent equal units of depth.

Gravitation is represented in this instrument by a column of mercury resting upon a corrugated diaphragm of thin steel plate, which in its turn is supported by the elastic force of carefully tempered springs representing a force independent of gravitation. Any change in the force of gravitation must affect the position of this diaphragm and the upper level of the mercury, which causes an air-bubble to travel in a convolute horizontal tube of glass placed upon a graduated scale, the divisions of which are made to signify fathoms of depth. Special arrangements were necessary in order to make this instrument *parathermal*, or independent of change of temperature, as also independent of atmospheric density, which need not be here described. Suffice it to say that the instrument, which has been placed on board the S. S. Faraday during several of her trips across the Atlantic, has given evidence of a remarkable accordance in its indications with measurements taken by means of Sir William Thomson's excellent piano-forte wire-sounding machine; and we confidently expect that it will prove a useful instrument for warning mariners of the approach of danger, and for determining their position on seas the soundings of which are known.

Another variety of this instrument is the horizontal attraction meter.

CERTAIN IMPROVEMENTS IN BLAST HEATING APPARATUS.*

By JAMES E. MILLS, B. S.

The process of reducing iron ores in the blast furnace, involves the escape from the furnace of a certain proportion of incompletely oxydized or burned carbon in the form of carbonic oxide gas, even when charcoal or coke or anthacite coal is the fuel used, and, in addition to this, nearly all the volatile matter of bituminous coal, when it is the fuel employed. So incomplete is the combustion in the blast furnace that, under very favorable circumstances, the amount of heat developed is only about forty-five per cent. of the total amount due to complete combustion in the case of coke or anthracite coal or charcoal; and in the case of bituminous coal, only about forty-five per cent. of the amount due to the complete combustion of its fixed carbon. Of the heat developed, a portion is carried off as sensible heat in the escaping gases, and only about one-third of the heat, which would result from complete combustion of the fuel employed, is available within the furnace when the fuel is in the form of fixed carbon, and a much smaller proportion when it is bituminous coal. And it is impracticable to carry the combustion or oxydation of the carbon much farther within the furnace than is now done in the best practice, because the farther oxydation of the carbon would prevent the deoxydation of the iron ore. Consequently, the greater part of the calorific effect of the fuel must be obtained, if obtained at all, by burning the escaping gases outside of the furnace, and this method of economizing fuel, though of quite recent date, is almost universally practised.

The heat thus obtained is partly used in raising steam, and so converted into power to drive the blast engine, and pumps, and other machinery of the plant, and a part of it is returned to the furnace in the blast.

The apparatus for conveying the heat of the burning gases to the blast (called hot-blast stove) is not without general interest to engineers, for, except apparatus for raising steam, perhaps no means of utilizing heat has been developed through more experimenting, or experimenting on a larger scale, since economy in the use of heat has become an exact science.

The blast passes through the apparatus on its way from the blowing engine to the furnace, and, consequently, under pressure which ranges from one and a-half to five pounds, or even more to the square inch. The amount of air to be heated, of course, varies with the consumption of fuel, but in favorable condition of working of furnace is from 3.75 to 5 tons, and frequently 6.5 tons or more to the ton of pig iron produced. The temperature to which it is desirable to raise the blast in a well designed, well managed furnace is at least 900° Far. Sir I. Lowthian Bell, the great practical investigator of the causes of consumption and means of economizing fuel in the blast furnace, considers that in a well designed furnace, of proper size, there is no gain in raising the temperature of the blast above 500° C. or 932 Far. But in some furnaces, at least, it has been proved economical to raise it to 1,200°, or even 1,400° Far.

In designing blast heating apparatus, therefore, we have to deal with very large volumes of air moving rapidly under pressure, to be heated to very high temperatures with fuel in gaseous state; and to provide against excessive friction and loss of pressure of the blast in passing through the apparatus, and against breakage and wear by expansion and contraction through a wide range of temperature, and oxydation by exposure of hot metal to air, and the warping and fusion and other destructive effects of the high temperature upon the materials employed in construction.

The various kinds of apparatus employed for accomplishing the work may be grouped in two classes. In one of these, the gases while burning, or after being burned, while still retaining the heat of combustion, are passed over masses of fire brick, which serve to catch and store up the heat within themselves

* A paper read before the Engineers' Club of St. Louis, Mo., April 5, 1876.

until they have reached the proper temperature, when the hot gases are turned off, and the blast is driven over them and takes from them the required heat. To make the process constant, there are two at least of such masses of fire brick through which the burning gases and blast are alternately passed. As a structure of fire brick cannot be made to be air-tight under the pressure and at the temperature produced, the masses are enclosed with a casing of plate iron. Such an enclosed mass of fire brick with its channels for admission, passage, and exit of gas and air, and its inlet and outlet pipes, and its valves for regulating the flow and changing the course of the gases and air, in its most developed form, is the Whitwell stove.

In the apparatus of the other class, the air is passed continuously through iron pipes, on the outside of which the gases are burning, and consequently receive its heat through the iron wall of the pipes. The pipes are arranged in an inclosed chamber, and the gases are burned in the same chamber, or in a combustion chamber beneath it. As the blast is inclosed in pipes, the brick walls of the chamber or stove do not require an iron casing.

The quantity of gaseous fuel escaping from the furnace is so large that the amount of heat which can be imparted to the blast is limited by the ability of the material employed in the construction of the stove, pipes, valves, &c., in which the blast is heated and conveyed to the furnace, to withstand the high temperature. The fire brick apparatus can, of course, bear much greater degrees of heat than any system of iron pipes, and, consequently, in the stoves of the Whitwell type, the blast can be raised to a much higher temperature than in the other class. The disadvantages of stoves of this class are large, first cost, considerable complication of parts, and great care required in the management of them.

The stoves with iron pipes have been much the larger in use, and on account of their comparatively small first cost and simplicity, will probably continue to be used quite generally, at least at charcoal blast furnaces; and it is an object of importance to improve the stoves of this general type to the highest practicable degree of efficiency and durability. They have gradually developed into rectangular brick chambers with the iron pipes conveying the blast arranged in straight rows, lengthwise or crosswise of the chamber, and the gases rising through long, narrow slits in the floor between the rows of pipes. The gases are either burned in the spaces between the rows of pipes, or in a separate chamber below the one containing the pipes, from which they pass up through the slits in the floor to the spaces between the rows of pipes.

There are two kinds of pipes in each stove: one kind, called bed pipes, consist of rectangular boxes, usually divided by a partition running lengthwise into two parts. These lie horizontally on the floor of the chamber. The other kind are of circular or elliptical cross-sections, and stand vertically upon the bed pipes and open downwards into them. They also are either divided into two parts by a diaphragm, extending from the bottom to near the top of the pipe, as in the so-called pistol pipe, or are doubled upon themselves, as in the so-called syphon pipe. In the case of the pistol pipe, the diaphragm rests on the partition of the bed pipe, or a projection of it, and one apartment of it opens downward into one apartment of the bed pipe, and the other apartment of the vertical pipe into the other apartment of the bed pipe; and in the case of the syphon pipe, one limb opens into the bed pipe on one side of its partition wall, and one on the other side. The blast enters the bed pipe on one side of its partition wall, and passes up through an apartment, or one limb of a certain number of vertical pipes, and down through the other apartment, or other limb of the same pipes, to the bed pipe on the other side of its partition wall, thence by a horizontal connecting pipe to another bed pipe, to pass through it and its vertical pipes in the same way, and so on to the outlet pipe. There are many modifications of this general arrangement, but the essential feature of the apparatus, as I have presented them, are common to all the best stoves of the class in general use.

There are serious avoidable defects in this general plan of stoves, which add to the first cost, and give rise to unnecessary wear of the pipes by oxydation

and bending and cracking, and also unnecessary strain upon the walls, and whenever the temperature of blast, sustained by one of these stoves, is near the point of safe endurance of iron, the destruction of pipes and of walls is a source of very considerable expense, and frequently of delay.

The rectangular form of the chamber gives rise to uneven reception and radiation of heat, and consequent uneven expansion and contraction of the walls, and renders necessary very strong binding with iron rods and angle-iron, and this does not generally prevent considerable bulging and cracking. The arrangement of pipes in rows parallel to two sides of the chamber leaves two interspaces in each chamber, bounded on one side by a wall, and on the other by a row of pipes, and the flame in each of these two interspaces presents one broad side to a wall, and radiates heat directly to it, or, as is usually the case, the flame is omitted from these two interspaces, and one side of two rows of pipes is without heat directly radiated from the flame. When the gases are burned in a combustion chamber, one side of two rows of pipes is out of the direct course of the hot gases, or the inner surfaces of two walls are in that course. Again, by the usual arrangement, or any convenient arrangement with parallel rows of pipes, one side or end of the chamber must be hotter than the other.

About two years ago it became necessary for me to plan a hot-blast stove for a charcoal furnace, to be built for the Midland Blast Furnace Co., and I had an opportunity to put into practice an arrangement which I arrived at in the endeavor to avoid the defects of the common plans, and secure the best practicable result from a stove of the class. The stove was built, and has been well tested, and the results of trial have proven the advantages of a plan which is theoretically—I think you will agree with me—better than those described; and to this I invite your more particular attention.

The stove proper has a cylindrical vertical wall, and a hemispherical roof or dome, like some potters kilns. The exposed surface, and consequent loss of heat by radiation and convection are, therefore, the least practicable, and so also is the amount of material in the wall. The absorption and loss of heat are very even throughout the wall, and consequently the different parts of it expand and contract evenly. The cylindrical form also reduces the necessary binders to simple hoops of sheet iron.

The pipes through which the blast passes are placed in rows arranged radially from near the center to near the circumference of the chamber; and the gases which serve for fuel are admitted through radial slits, one in each sector of the floor, and burned in the spaces between the rows of pipes. Therefore, each sheet of flame presents both broad-sides to rows of pipes, one on each side, and each row of pipes receives heat directly radiated from flame on both sides of it. There are six such rows of pipes, and consequently six interspaces and six sheets of flame in the stove actually built.

The blast coming from the engine enters a drum near the roof, and passes from it by six pipes, extending outward and downward near the roof and wall of the chamber to the outer end of each of the six rows of pipes, and thence passes through the six rows to a drum in the middle, a little lower than the drum before mentioned, and thence by an outlet pipe towards the furnace. The slits admitting gas through the floor approach one another as they approach the center, and consequently the proportion of flame to space increases toward the center as far as to the inner ends of the slits. To insure complete combustion, there is a chimney rising from the middle of the dome. The air for combustion is admitted through the outer wall at the level of the floor by an opening opposite the end of each of the slits which admit gas. The tendency of the hot gases and flame is toward the middle of the stove. The blast therefore travels in six streams toward the hottest place in the stove until it reaches the outlet pipe.

The nearness of the drum and pipes, which first receive the blast to the roof and outer wall, combines with the direction in which the blast travels, and the position of the flame, and the direction of the draught, to keep the outer parts of the chamber cool, and to reduce to the minimum the loss of heat through

the walls, and the destructive effects of heat upon them.

I will now describe more in detail the stove which was built on this plan, and which is represented by the accompanying drawings.

The inside diameter of the cylindrical building is 18′ 6″, and the radius of the dome 9′ 3″. The height from the floor to the edge of the dome is 12′ 4″, and to the center of the dome 21′ 7″.

The foundation consists of a wall of sandstone rubble 2 feet high and 18 inches thick.

The vertical wall is of fire-brick, 13½″ thick, except the upper one foot, which is 18″ thick, projecting outward 4½″. The dome, which is also of fire-brick, is 9″ thick. It rests on the inner 9″ of the vertical wall. Outside of it on the vertical wall, and flush with the outer surface of the latter, are laid thirteen courses of red brick, thus continuing the vertical surface of the wall on the outside about 31″ higher than the lower edge of the dome, and encircling the lower part of the dome to that height.

The walls is bound by three hoops of plate iron, $\frac{3}{16}$″ by 4″, one at the upper edge of the vertical outer surface of the wall, one at the level of the lower edge of the dome, and one 8′ from the ground.

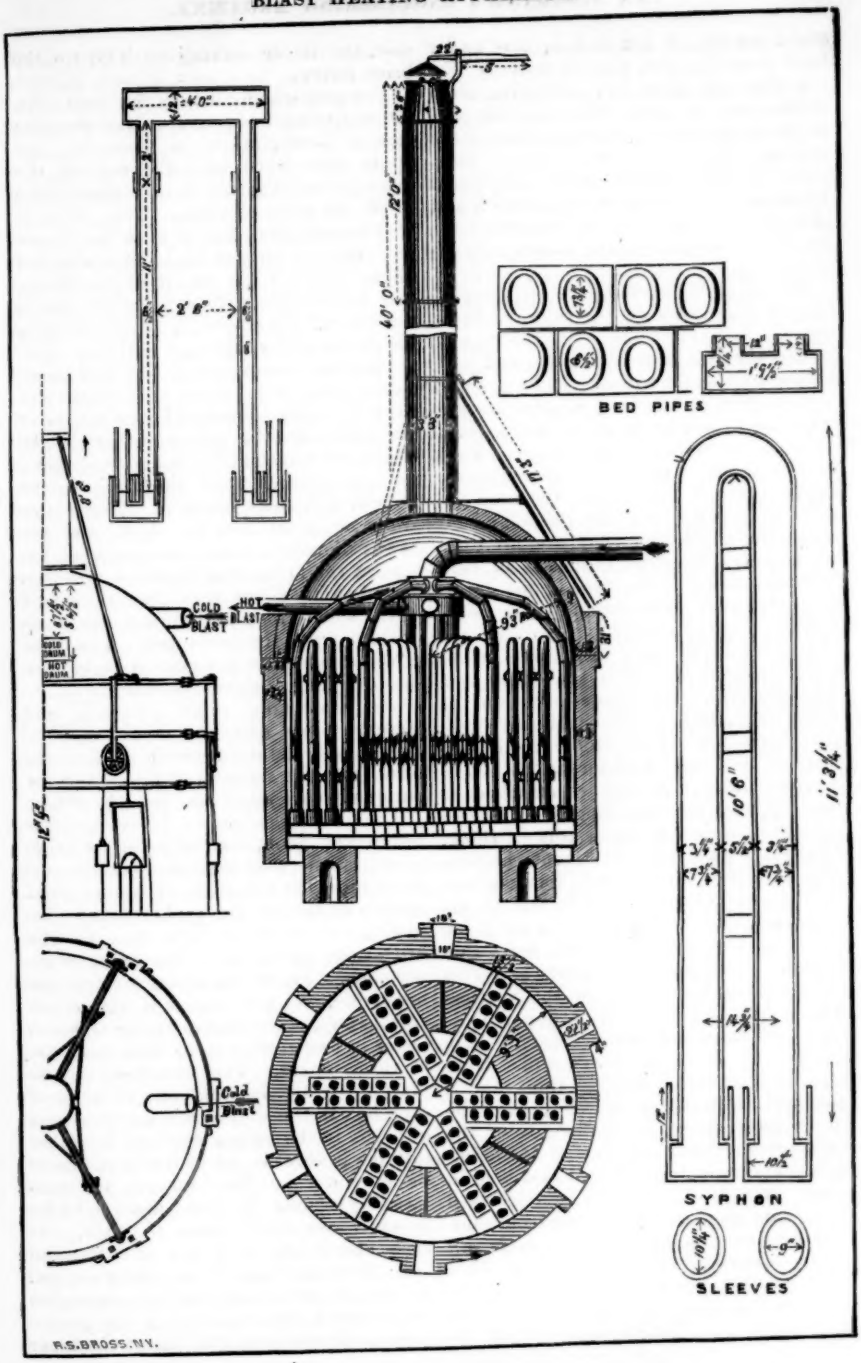
There are six small arched doorways in the vertical wall, at equal distances from one another opening into the chamber mid-way of the outer side of the interspaces between the rows of pipes. They rise from the floor of the chamber, and are 4′ high to the crown of the arched upper end, and 15″ wide below the spring of the arch on the inner side, widening outward as much as due to radial position of the sides. The doors are simple plates of fire-brick or tiles bound around the edge with a wrought iron band, to be opened and closed by being raised and lowered by pulleys. To afford a sloping surface for the doors to rest and move upon, the jambs of the doorway and a portion of the wall above are made to project, beginning at a point twice the height of the doorway, or 8′ above the ground, and increasing downward so that the projection at the ground is 9″. By this arrangement, iron doors exposed to flame are avoided, and, moreover, the opening for admitting air, being made by raising the door, is at the bottom of the chamber. These doors have not yet been put on, but, instead, the doorways were filled in with fire-brick leaving only small openings at the bottom to admit air.

On both sides of each doorway is a peep-hole of the size to be closed by a brick placed in endwise.

The doorways are large enough to admit the passage of the pipes and bed-pipes, but not of the drums. For admitting these, a portion of the wall is arched over, so that it could easily be taken out and replaced.

The flue for admitting the gas passes around under the floor and is annular, and its middle line makes a circle 12′ in diameter about a center, directly under the center of the chamber. It has a branch opening into it from the furnace. Where it passes under the walls of the building, or the foundation stones upon which the pipes stand, it is arched over, and its cross-section is 18″ wide up to the spring of the arch, and 1′ high to the spring, and 1′ 9″ to the crown of the arch, but under the interspaces between the rows of pipes its walls continue vertical to the top, and it is covered over with broad tiles, excepting a slit 3′ long, nearly in the direction of the radii of the chamber, and 3″ wide. To obtain the length of three feet, the slit is extended by a groove cut into the wall of the flue on either side. The slit can be narrowed and shortened at will by bricks placed on top of the tiles, and moved from outside through the doors by a rod. The wall of the flue is 12″ thick. The tiles covering the flue on each side of the slit can be raised, and through the openings thus made, a man can reach the ashes and dust in the flue with a hoe and move them toward the branch that comes from the furnace, and from the branch they can be easily raised outside of the stove. To facilitate the removal of the dust and ashes, and render it practicable while the stove was hot, or, comparatively so, three openings were made to the flue from outside, but they were not used or needed, because, on account of the proportion of the area of cross-section of the flue to the volume of gas moving through it, the dust and ashes did not accumulate in quantity to materially hinder the flow of the gas.

The foundations upon which the pipes


BED PIPES
SYPHON
SLEEVES
COLD BLAST
HOT BLAST
R.S.BROSS.N.Y.

stand consist of six stones, one under each row of pipes, placed radially like the rows of pipes, and extending from within two or three inches of the wall of the chamber to within one foot of the center. They are about 8′ long, 1′ deep and 2′ 3″ wide, except at the inner end where one vertical edge is truncated and the stone narrowed to fit the space for it. The material of the stones is sandstone.

A wall of fire-brick 4½″ thick is carried up from the floor by the sides of these stones between them and the spaces where the gases are burning, and still higher by the sides of the bed-pipes and the sleeves at the foot of the upright pipes, to a height in all of about three feet. These walls, within the outer walls of the chamber, inclose on the sides the lower part of the spaces between the rows of pipes where the gases and air enter and meet, but they are all open above, and the free radiation of heat from the flame to the pipe is but slightly obstructed. The chimney rises forty feet above the dome, is of sheet iron (No. 14) and is lined with three inches thick of fire-brick from the dome to a height of 10′. Its diameter within the lining is 3′, and above the lining 3′ 6″, till within 2′ 6″ of the top where it narrows so that the diameter at the top is 2′ 6″. There is a damper attached at the top, and for two lengths of sheets (about 5′) below it the iron is $\frac{3}{16}$″ thick. There is a guy band 12′ from the top. The weight of the chimney does not rest on the dome but is transferred to the upper edge of the vertical wall by three pieces of rail-road rails which serve as a tripod. Their outer and lower ends rest on cast-iron feet lying on the vertical wall. At their inner and upper ends they are attached to the chimney at a point 8′ 6″ above its lower end. Here also is a sheet of iron $\frac{3}{16}$″ thick and a wrought iron band 6″ × ½″, and the rivets pass through the flanges of the rails and the band and iron of the chimney. The rails are stiffened and held in place by rods of ¾″ round iron inclosed in 1¼″ gas pipe, and extending from midway between the two ends of each rail to the lower end of the chimney. This end of the chimney is stiffened by a wrought iron band 4″ × ½″ on the outside, and a piece of 2″ angle iron on the inside, the latter serving to hold up the brick lining.

The pipe which conveys the blast from the engine to the apparatus is of wrought iron ½″ thick, is 16″ in diameter, and opens downward into the top of the drum, from which the blast is distributed to the six rows of pipes. This drum is of wrought iron, and is 2′ 10″ in diameter, and 1′ 3″ long or high. It is situated directly under the center of the dome, and its lowest surface is 14′ 9½″ above the floor of the chamber. It has besides the openings for inlet and outlet of blast, three small man-holes, closed with small man-heads, large enough to admit the hand and arm. Around the periphery of the drum are six cast iron thimbles, to which are attached by flanges and bolts the pipes which take the blast to the ends of the rows of pipes. These also are of wrought iron ⅛″ thick, and are 7½″ in diameter, inside measurement, except at the lower end where they are enlarged to lap down over the upper part of the short pipes or thimbles projecting upward from the bed-pipes. The joint at this connection is rendered tight by a sleeve 1′ long, and rust packing.

The remaining pipes (syphons and straight pipes and bed pipes) and the sleeves and the drum which receives the blast from the six rows of pipes, and the outlet pipe are all of cast iron, ¾″ thick.

The bed pipes consist of rectangular boxes, 21½″ long, 10½″ wide, and 6″ high —all inside measurements—with two short pipes or thimbles of same cross-section as that of the syphon pipes, projecting 4″ upward from one of the broadsides, and open at the outer or upper ends. The boxes lie on the opposite broadside, and are placed in six sets of radial rows, each set consisting of seven boxes in two rows, one of four, and one of three boxes. The two rows are so placed side by side that one thimble of each box in the shorter row is abreast one of a box in the longer row, and the other thimble is abreast one in the next box of the longer row. The two rows are separated by a space 1¾″ wide, and the boxes in each row by a space 1″ wide. At each end of the long row is a thimble not paired with one in the shorter row. To the one at the outer end is connected the wrought iron pipe which brings the blast to the row, and the one at the inner

end opens into the straight vertical pipe which takes the blast to the drum which receives it from all the six sets of rows. On the six intervening pairs of thimbles stand the syphon pipes. One limb of each syphon stands on a thimble of one row, and one on a thimble of the other row, and by the arrangement of the boxes or bed pipes, each bed pipe in the short row receives air from one in the long row through one syphon, and delivers it through another syphon to another box farther on in that row, and so the blast passes from row to row and forward till it reaches the last box of the long row, and passes from it through the straight vertical pipe to the drum which delivers it to the outlet pipe leading toward the furnace.

I have called the rows radial. The middle line of the long row of boxes or bed-pipes is exactly radial: of course the other row is not exactly radial and the divisions of the floor of the chamber between the sets of rows are not exactly true sectors of a circle. The slit for admission of gas is placed midway between a short row of pipes on one side and a long row on the other, and each door is opposite a slit.

The syphons have an elliptical cross-section with diameters $6\frac{1}{2}''$ and $7\frac{3}{4}''$, inside measurement. The centers of the two ends are $14\frac{3}{4}''$ apart, and the pipes are so doubled upon themselves as to bring the long diameters of the two limbs into line. It is $11'\,\frac{3}{4}''$ from the lower ends to the top of the curve of the outside of the pipe at the junction of the two limbs.

The straight vertical pipes at the inner end of the rows have the same cross-section and are 11′ long.

The drum which receives the blast from the six rows of pipes and delivers it toward the furnace through the outlet pipe is a cylinder $3'\,10\frac{1}{2}''$ in diameter and 1′ long or high, inside measurement, with a pipe or thimble 1′ in diameter (inside) and 4″ long projecting from the periphery, which connects with the outlet pipe, and six pipes of same cross-section as the vertical straight pipes, and two feet long projecting from the lower end. These pipes rest on and open into the six upright pipes. The centers of their inner ends are each $1'\,7''$ from the center of the bottom of the drum, and a line connecting them would form a hexagon with sides of $1'\,7''$.

The outlet pipe is 1′ in diameter inside measurement.

The connections of the different castings are all made with sleeves and rust packing, the space between the sleeves and the pipes filled with the packing being $\frac{1}{2}''$ wide. The sleeves therefore have a diameter 1″ greater than the outside diameter of the enclosed pipes. A part of the sleeves are 8″ and a part of them 12″ long. I would now make them all of the latter length so that the packing might extend 6″ either way from the joint, and for this purpose would make the thimbles on the bed-pipes and the one on the drum 6″ instead of 4″ long.

The amount of material in the whole apparatus is as follows:

Principal Castings (by actual weighing).	
42 bed pipes (average weight, 228.88 lbs.)	9613 lbs.
36 syphons (average weight, 1546.17 lbs.)	55662 lbs.
6 straight vertical pipes (average weight, 703.5 lbs.	4219 lbs.
90 sleeves, 62-9″ long (average weight, 64.9 lbs.)	4024 lbs.
90 sleeves, 28-12″ long (average weight, 85.9 lbs.)	2405 lbs.
1 drum	2053 lbs.
1 outlet pipe*	955 lbs.
1 sleeve to latter	184 lbs.
Total	79115 lbs.
Or $35\frac{715}{2240}$ tons, essentially $35\frac{1}{3}$ tons.	
Wrought iron pipes and drum and inlet pipe,† together with the small cast-iron man heads and thimbles and flanges about	2200 lbs.
Wrought iron of the chimney, including cast iron damper (by actual weighing)	2382 lbs.
Three pieces of rail forming the tripod of chimney, about	850 lbs.
The $\frac{3}{4}''$ round iron and $1\frac{1}{4}''$ gas pipe serving as braces to the tripod	123 lbs.
The castings on which the rails of the tripod rest, about	253 lbs.
The wrought iron about doors and attachments, about	400 lbs.
Cast-iron pulleys to doors, about	300 lbs.
The three draw-bands or hoops encircling the wall of the building (by actual weighing)	1060 lbs.
The fire-brick work in the building, including as much of the flue as is under the building, all tiles, lining of chimneys, &c., about 1315 cubic feet, or calling the cubic foot 20 bricks	bricks. 26,300

* The part of the outlet pipe extending from the drum to the outside of the building.

† So much of it as is within the sto

The red brick, 150 cubic feet, or ...3,000 brks.
Stone in the foundation of the wall of the building.....206¼ c. ft.
The six foundation stones of the rows of pipes..... 123 c. ft.

The service thus far actually performed by this apparatus is as follows :

The furnace to which it was attached was in blast 137 days. After the first three days the blast was maintained very steadily at 900° Far. to the end of the campaign, or 134 days. The amount of air or blast heated to this temperature averaged during the time 2723 cubic feet per minute ; and for a considerable portion of the time was over 3000 feet. The reports based on the number of revolutions and size of the blast engine make the amount of blast very much larger, but to avoid all error by leakage of pipes and other causes I have given the amount received by the furnace calculator on the basis of fuel consumed and probable composition of gaseous products of combustion.

The Superintendent,—Mr. William E. Rowell—informs me that in arriving at the temperature of the blast he carefully checked the readings of the guage by means of the fusing point of alloys.

The building proper shows no harmful effects of heat. The wrought-iron pipes and drum are also I believe, as good as when put in. No one of the cast-iron pipes or bed pipes is cracked or burned through, nor is the drum. One or more of the six upright pipes are somewhat bent from the weight of the drum and outlet pipe bearing upon them while hot, and I would in future take this weight off by a small fire-brick pillar rising to the drum from the center of the floor of the chamber. Some of the joints leaked on account of defective packing. The pipes and flues were not cleaned during the campaign.

The apparatus performed all that was required of it for the furnace to which it was attached, without at any time being forced to the limit of its capacity or endurance, and yet I think all who are familiar with the subject will agree with me that the performance recorded is unusually large considering the size of the stove and the amount of material used in its construction : and that it withstood the effects of the high temperature maintained during the campaign with unusually slight wear or destruction of parts.

SOME MODERN IMPROVEMENTS IN HOUSE BUILDING.*

From "The Builder."

I PROPOSE to depart somewhat from the subject advertised in the syllabus, and refer to some of the modern improvements in house-building, believing that instead of describing a few of the most recent improvements possibly hardly tried, it would be more profitable to consider the relative merits and demerits of certain materials and improvements that have stood the test of time to a greater or less degree, and with which we all have some acquaintance,—in the hope that, in the discussion that will follow this paper, members will give the result of their experience ; and, with a view to prevent the subject becoming too wide, I propose to limit the paper to those improvements that pertain to house-building.

It may be assumed that the object of inventors in introducing new materials and modes of workmanship for house-building may be classed as follows : 1. To promote health and comfort. 2. To cheapen the cost of building. 3. To save labor in the work of the household. The first is necessary to render a house truly a home, and the advance in scientific knowledge naturally conduces to improvements, especially in reference to sanitation. The second is a matter of considerable importance in these days when the cost of labor, and consequently the production of all hand-made articles, is materially increased. The third is rendered especially desirable, now that

* A lecture before the Architectural Association, by Mr. J. Douglass Mathews.

domestic service is so little sought by those who, in the natural course of things, are fitted for this work. In order to systematize the paper, I propose to consider the subject as far as possible in the order of the trades engaged in house-building, and without further preface proceed to commence with the foundations.

It is generally admitted that in all foundations, except rock, firm gravel, or compact sand, a layer of concrete should be thrown in trenches, the extremely uncertain nature of clay especially requiring it. Much alteration is now made in the admixture and manner of using this material. Formerly, ballast and stone, or chalk-lime, were used in the proportion of three or at most four to one, and the concrete thrown from a stage seven feet high; *now*, recent experiments show that good burnt ballast, broken bricks not exceeding about two inches square, and a little sand used with the ballast, may be used in the proportion of five, and some say as much as eight, parts to one of good fresh ground or selenitic lime, and that the concrete sets much better in bulk if it is shoveled into the trenches in layers not exceeding one foot in thickness, instead of being thrown from a stage. In all cases where there is any water blue lias lime should be used, or Portland cement. A great safeguard to prevent damp rising, and to render a house warm and healthy, is to spread a layer of Portland cement concrete, about four inches thick, over the whole site, especially on a clay site or one of made ground. The prevention of damp rising in the walls is a matter requiring careful attention. The plan of using a double course of slates, with three layers of cement, is good if the workman can be trusted to make the beds perfect, and to break the joints of the slates; but in case of settlement the slates will break and the wet find its way up the wall. A strong coating of tar and sand is a good damp course, but the same objection in case of settlement applies to this. Engert's asphalted felt damp course is, I think, as good as any; it is cheap, easy of laying, and will accomodate itself to settlement, but care must be taken to properly lap each sheet. Taylor's stoneware perforated damp course is advantageous, being perfectly damp proof, and affording at the same time ventilation under the floor, as well as acting as a good bonding course near the base of the wall; but its cost will, I fear, prevent its general use in house-building. The means of keeping a basement dry is a problem that is difficult to solve. The usual plan of a so-called dry area is at all times unsatisfactory; often the covering gets broken and the rain enters, or the area becomes wet instead of dry, thereby causing a damp atmosphere outside the wall, which in time draws through it, and occasions the wall to be constantly wet. If dry areas are used they should have a field drain-pipe laid in the bottom, connected with the main drain, a strong covering not likely to get broken, proper air-gratings used to ensure a current of air all round; and, in case of ties, the ends of the bricks should be coated with tar. A good plan would be to build a hollow wall with a space of about two inches tied in with vitrified bricks, and liquid tar and sand poured in to fill up the cavity between the two walls. It would be more satisfactory in all cases if cement were used for rendering the inside of basement walls instead of plaster, or, better still, asphalt.

The great demand for bricks in the metropolis, and the frequent transformation of suburban brickfields into "eligible building land," cause at times great scarceness, and, by reason of land or water carriage, always considerable increase in the price compared with that formerly. The adoption of some other, or at any rate additional, material for the construction of walls is, therefore, forced upon us, and this material appears to be concrete, which, I believe, may be considered the building material of the future. Of its use in former times, and its advantage as a building material for modern dwellings, I have had occasion to speak before in this room, and its extended use during the last ten years affords us the opportunity of finding out its merits and defects. The introduction of Portland cement and selenitic lime has done much to enable this material to be used in a way that it never could have been had ordinary lime only been available; but it may be a question whether, notwithstanding the increased strength and consequent decrease in the

thickness of walls obtained by the cement, it is desirable to risk its use in such small thickness as some suggest and adopt, as the whole strength of a concrete wall is dependent wholly upon its homogeneity, which may be disturbed by imperfect foundations or other causes. The methods adopted for its use hitherto have been principally in the monolithic form, by constructing temporary trenches by means of sliding uprights and boards, and filling in about two feet each day. One of the advantages claimed for this process is, that, as the scaffold is supported by the wall built the previous day, should there be any fault in the cement or in the admixture of the concrete, it is at once found out. The chief drawback is the expense of the apparatus, which, however, would be greatly reduced in proportion to its extended use. To obviate this expense an apparatus has been patented whereby the boards used for the roofs or scaffolding may serve as temporary trenches, and the uprights to support them made to slide as telescopes, instead of being set up so frequently, as by the other plan; but this method has not the advantage of proving bad work so readily as the other, and in concrete building, more, perhaps, than in anything else, good work is an absolute necessity. There is no doubt that the only way to use concrete as an economical material, and as one cheaper than bricks, is in the monolithic form; but I cannot help thinking that it would be safer, if not more lasting, to use it as a filling or core, the wall being built in such a way that proper bond may be preserved, as, for instance, by cement blocks cast hollow. Terra cotta might be also used for the facing only, trusting to the concrete for the strength of the wall. A system of this kind has lately been introduced by Mr. Sellers, of Birkenhead, the blocks being formed of a concrete composed of sand, stone, and Portland cement, and each block bonded to the other by means of a kind of beaded tongue and groove. Tiles ⌊-shaped, and of the size and texture of an ordinary brick, are made, which are built in courses as bricks on the outer and inner face of the wall, and concrete filled between. Ordinary bricks have been used as an outer and inner face, with bonding bricks or courses at intervals, and the cavity filled in with concrete, but these methods are all more or less expensive, and can only be cheaper than ordinary brick work where great thickness is required for strength or appearance. In passing through Staffordshire and other iron counties, one cannot but be struck with the apparent waste, not to say defacement of the country by the mountains of scoriæ from the furnaces, for which little or no use has yet been found, but in the economy of nature this cannot be intended to remain long without a purpose. Why may not this be used in the manufacture of hollow blocks such as I have mentioned? The answer, doubtless, would be that, when exposed, the weather would act on some of the ingredients, and disintegrate, and finally perish them. If this is so, is there no system of indurating or water-proofing, such as Ransome or Szerelmey *has* invented, or as some equally enterprising person *could* invent? This method would admit of considerable variety of architectural treatment, as the blocks could be cast with any ornament, sunk or otherwise, and would have advantage over a cemented front of being truthful in appearance, on account of the building being erected course by course. Whilst speaking of architectural treatment I may remark that some of Soane's or the Adams' buildings may be studied with advantage in ornamenting concrete, as flat or slightly projecting features are far more suitable than heavy ones; and for this purpose sgraffito has been used with very good effect in some recent buildings —an example which will no doubt be largely followed. One great impediment to the extended use of concrete by architects is the necessity for cementing the external face. But I believe this arises a great deal from prejudice, as the value of cement as a material is admitted on all hands; and, had it not been used largely as a cloak to hide bad work and materials, and in a manner to imitate stone, I venture to think it would have been considered a fair and legitimate method of facing and ornamenting buildings.

The necessity of adopting some new material for a general roof-covering is almost as great as for walling,—at any rate, if the supply of slates continues as short and the price as high as at present.

For general purposes there is no better material than slate, chiefly on account of its lightness, and the comparatively flat pitch at which a roof can be constructed, both of which tend to lessen the cost of the timbers of the roof. For appearance and comfort, tiles are preferable, but they require a sharper pitch in the roof, and, being much heavier than slate are more expensive both in original cost, in labor in laying, and in the strength of roof-timbers. A lighter roof is formed by the Broomhall tiles, which also have the advantage of being fixed easily; but the price is too high for general use. Recently the Somerset tiles—such as the corrugated, Roman, &c.,—have been much used about London, and, as the price is very little more than the ordinary pantile, and the labor in laying the same, they have been largely in demand for covering small houses. If a superior tile were made, of a better and more uniform color, they would doubtless be greatly used. These tiles require torching on the inside after laying, and their chief defect is the very small lap to each tile.

They are very porous; but I believe a coat of tar on the inside is a great improvement. A tile has lately been introduced, called the bonding roll roofing tile, which, according to the description, has the advantages of breaking joint, and thus preventing wind-stripping, a perfect bed, the corners not cut, and the ease with which the new tiles can be inserted. The price is moderate, and if the color is good, it appears to me to be likely to supply the demand now created. The designs for the tile ridges are much improved, and the cleverly-modeled finials and terminals lately introduced add wonderfully to the effect of the roof.

Before considering the construction of floors I may remark generally on the difficulty of getting well-seasoned timber. In no way is the effect of competition shown more strikingly than in this: timber is, in many cases, brought direct from the dock to the ground, cut up and used at once in the building, shrinkage ensues, and cracks in plastering of partitions, ceilings, and sometimes in brickwork, are the necessary result. Formerly a builder would keep timber for years in his yard before use; but, except with large firms, capital is too valuable to allow of its lying idle in the shape of timber stacks.

There are many advantages in the use of a concrete or iron floor; and here, again, I would say that I believe concrete is capable of further development. The system of fireproof flooring has been much cheapened by the use of rolled joists, filled between with slabs of concrete; but the cost, however economically used, compares unfavorably with an ordinary wooden floor, chiefly on account of the boards and joists. Homan's or Phillip's plan of laying iron joists two feet six inches apart, filled in between with concrete, and rendered doubly secure by the use of light T bars, varying from two inches to twelve inches apart, makes a good and economical floor. A plan adopted by Messrs. Moreland is to lay strong iron joists or girders about eight feet distant, with light iron bow-string girders about two feet six inches apart. The concrete passing through the interstices of the iron truss forms one continuous slab from wall to wall. The most inexpensive mode of forming concrete floors that I have seen is that invented by Mr. Allen, and used in the Waterlow dwellings, which consists of rolled iron joists about six feet or eight feet apart, with a wrought iron bar, about three inches deep, laid on top; this is drilled for, and light iron rods, about one and a half inches in diameter, run from one to the other, and the whole is encased in concrete six inches deep. In each of the foregoing the ordinary wooden floor is laid above with shallow joists. Mr. Lascelles has recently patented a plan by which concrete is used in slabs or tiles, and when used for a floor the tiles are laid on iron or wooden joists the width of the tile apart. The slabs being faced on both sides serve for floor and ceiling at the same time. I believe in some concrete houses the floors have been finished with Portland cement, and a fillet laid round the room flush with the floor for the purpose of nailing the carpets. If wooden borders are required, parqueterie or ordinary wood could be laid round, of the width required, and the moderate price at which this material can now be obtained, compared with the effect produced, is a great inducement to its use. If an entire wooden floor were needed, wooden blocks or

bricks about one and a-half inches thick (introduced by Mr. W. White), similar to those often used in schools and churches, make an excellent floor. In all basement floors the use of the solid blocks, properly Burnetized, is recommended, because thei ruse does away with the need of ventilation under the floors, which is often very imperfect, and it also saves at least twelve inches in the height of the walls all round.

A substitute for the wood-framed quarter partitions is much to be desired. It is impossible to divide all the rooms on the upper stories in the same manner as below, and therefore brick walls cannot be carried through the house. To meet the difficulty, partitions must be used, and these are best formed as a truss, throwing the weight on the walls rather than on the floor. If these partitions are formed of timber, shrinkage is sure to take place, and with it cracks in the plastering of the walls and ceilings, which, to say the least, is unsightly. A truss formed of iron and the partitions built in hollow bricks or concrete blocks would answer the purpose if cost were not an object. Wherever partitions are set one above another, or on brick walls, it is best to use nogged rather than quarter partitions.

One of the advantages of railway conveyance is the increased facility for procuring stone. This is proved by its almost universal use in dressings, even in small houses. The stone to be adopted must, of course, depend on the locality, and before building care should be taken to ascertain the relative advantages and disadvantages of the local stone.

Two or three kinds of artificial stone are manufactured, and which are really concrete. Ransome's Patent Concrete Stone, which has been the longest in use, has for a time, at least, I believe, ceased to be made in London. This, however, I think, arises more from the difficulty of overcoming the prejudice which exists with all new materials than from faults in manufacture. A stone of a somewhat similar nature, called the "Patent Victorian Stone," has been more successful, probably because the manufacturers laid themselves out more for the practical than the artistic. Much of the paving, sinks, &c., made by this company, some years ago, have stood the test of time well, and in cases where repetition of an article is required it competes successfully with natural stone. Another artificial stone, which is concrete, composed of coal breeze and Portland cement, is made by Mr. Matthew Allen, who claims for it extreme durability, and recommends its use in steps, paving, &c.; and, being a moulded material, the cost is much less than stone.

Terra cotta as an ornamental material has not found favor to the extent its strength and durability demand, but for ordinary work this is scarcely to be wondered at, as the expense of modeling, moulds, &c., in addition to the actual casting, is very great, so that even with a fair amount of repetition its cost exceeds that of stone, and this, added to the uncertainty in delivery and risk of imperfect castings, causes it to find but little favor with the ordinary house-builder.

The introduction of selenitic lime is a great advantage to plasterers, as its quickness in drying enables each coat to be followed on almost immediately, thereby saving much labor in shifting scaffolds, &c. Whether it fulfills all the advantages claimed for it, is a matter which my own experience will not allow me to say, but having adopted it on several occasions, I am satisfied with the result.

The use of carton pierre has largely increased as an ornamental material to supersede plaster, and the castings are as a rule sharp and well executed; the lightness of the material, and the ease in fixing are also advantages in its favor, but, like all cast materials, it requires care in fixing, because, being in short lengths, the lines are not always perfectly true.

It is somewhat remarkable that no substitute has been found for the ordinary plaster ceiling. Two materials more opposed to each other than timber and plaster could hardly be found—the one almost naturally deflecting, and the other as surely cracking. Possibly the chief, if not the only, reason for its continued use is that plaster is in a great measure fire-proof. If some such material as carton pierre could be made fireproof it might be screwed up to the ceiling in slabs, and, if necessary, the joint covered by an ornamental moulding

or rib to form panels. Since writing the foregoing, I find that a system has lately been patented which in a great measure meets my suggestions. Mr. Hitchins forms slabs about a yard square, prepared in a somewhat similar manner to carton pierre, and secured with zinc nails to the joists; the slab being rough has a setting coat either in plaster or Parian cement laid on in the usual manner, after it is fixed, which effectually conceals the joists. The edges of the slabs being bevelled, each one forms a kind of dovetail into the others. A ceiling by this means is very quickly and cleanly put up, and the cost is very little beyond that of ordinary plaster.

The substitution of cement for wood skirtings is an advantage, preventing a harbour for vermin and a run for rats and mice, and, if used with a concrete-floor, these undesirable domestic pests would be almost exterminated.

Notwithstanding the enormous increase in the cost of almost every building material during the last few years, the ordinary joiner's work proves in a great measure an exception; this is accounted for by the admirable machinery which has from time to time been invented for saving manual labor, and which has now arrived at that state of perfection that a door may be prepared in every part, even to the sand-papering, by machinery, excepting only the wedging and pinning together and mitreing the mouldings. The circular band-saw affords great facilities for executing ornamental fret and curved work, at a very moderate price. Machinery being now so generally used, joiners' work should be specially designed for its manufacture n this manner, as handwork, such as special mouldings, greatly increases the cost without in the ordinary way producing a corresponding effect, and especially as the cost of making a special plane for working mouldings to design is in most cases almost nominal.

In no part of the inside of a house has more care been of late bestowed than in the design of the staircase, and, it must be admitted, with satisfactory results, the newels and balusters affording a good opportunity for architectural treatment; but it is worthy of remark that the too frequent use of sinkings and multiplication of small mouldings, although effective in drawing, and possibly in execution, should be avoided, as they form capital receptacles for the accumulation of dust, which in a short time becomes a cake of mud.

The introduction of hand-painted tiles has been the means of causing the stereotyped marble chimney-pieces to be in a great measure superseded, and the admirable way in which they have been used in connection with wood has given an opportunity for design that will not readily be given up. Some excellent printed tiles have been made, well drawn, and extremely moderate in price, and well adapted for chimney-pieces and wall linings. In connection with chimney-pieces tile hearths may be mentioned as an improvement not only in appearance, but also on account of their cleanliness.

Much attention has been given of late to the design and manufacture of stoves. Instead of being limited to the two or three descriptions of the well-known register, we have now a large variety of stoves, all claiming advantages, either in economy, in heat, or in saving of coals. The wasteful way in which we Englishmen use coals is admitted on all hands, and when, a winter or two ago, the price of coals became so enormous as to produce almost a famine, the direction of stove manufacturers was naturally led to devise some plan for their more economical use. Without attempting to describe all or any of the improved stoves, they may be classed under three heads: First, those that warm the air admitted from without and deliver it in an upper room or other portion of the house. Second, those that provide means for delivering the warmed air in one or more parts of the room in addition to the fireplace. Third, those that by polished surfaces reflect the heat, or by fire-clumps or other substances retain the heat. All these descriptions make use of the ordinary open fire, and for the purpose of house-warming, as well as for comfort, it is not probable that this form will be speedily abandoned. At the same time, notwithstanding the improvements and the economy resulting from the use of the heated air at the back of the stove, which was formerly lost, a considerable portion passes up the chimney without being available for the purpose of the

house, and there does not appear to be any means of remedying this, unless the smoke is again passed through the fire, as is the case with the smoke-consuming apparatus fitted to boiler furnaces. The introduction of air from the outside of the house to supply the stove is advocated, and doubtless for the comfort of the inmates it is better that the fire should be fed in this manner rather than by the air in the room; but I believe this plan increases, rather than diminishes, the quantity of coals consumed. The extended use of kitcheners is fast superseding the open fire-ranges, although the latter have advantages that will commend them to some people; but the conveniences possessed by the close ranges give great facilities for cooking in a small space. It is somewhat surprising that the independent cooking-ranges, such as are in almost universal use abroad, are so little adopted. Several kinds have lately been introduced to stand in a chimney-opening without any setting. The front and sides, as well as the top, are available for cooking purposes, and the cost is much less than the ordinary range, whilst the saving in fuel is considerable. Possibly, now that the culinary art is being taken up as an accomplishment for ladies, and as part of the higher class education for girls in board-schools, we shall have corresponding improvements in kitchen-ranges.

We now pass on to the plumber, and in this trade probably more than any other have the inventors and patentees been hard at work. The recent regulations of the Board of Trade, requiring the Metropolitan Water Companies to furnish a constant instead of an intermittent water-supply, within a certain number (I believe now about nine) years has occasioned an entire alteration in the system of water-fittings to houses. From the time the regulations were issued, all new buildings were to be furnished with pipes and fittings suitable for a constant supply, although for the time being the supply is continued as heretofore. The chief end gained will be, that instead of water being rendered impure by storage in a cistern, it will be drawn direct from the main, and except for a supply in case of emergency, cisterns may be altogether dispensed with. The service-pipes being always charged, must, of necessity, be very strong, and therefore the heaviest pipes that are made are used, although, where ¾-inch pipe was formerly used, ½-inch will now be sufficient. The ordinary bib-cocks are not suitable for high-pressure, because with a full way, the weight of water would be too great for convenient use. Screw-down high-pressure cocks are substituted; and although these prevent the force of water at once, they are open to many objections, chiefly from the slow process of turning the water on and off, which, in nine cases out of ten, to save trouble, is left running, and thus occasions a considerable waste. Possibly some day we shall have an improved high-pressure cock invented that will remedy these objections. Another great alteration is, that all closets must be fitted with a water-waste preventer, so called, or, in other words, a means of storing two gallons of water to discharge into the water-closet pan, without taking the supply direct from the cistern or main. There are so many water-waste preventers now in use that it is desirable to find what is generally used in the particular district, and to adopt it, as, so long as the water companies enjoy their monopoly, they can require any fitting they may please to be used, and refuse to lay on the water until it has been altered. In some of these preventers I believe it is imperative that two gallons of water should be discharged every time the closet is used. This in some cases is a waste of water, and in others not sufficient, especially as the flush is so feeble, by reason of the preventer being fixed so near the apparatus. The use of these preventers does away with the expense of a regulator-closet, which is an advantage, and the simpler and less complicated the water-closet apparatus the better for use.

Earth-closets have now been adopted for some years, and where the soil can be made use of in the garden or fields, they are advantageous. The chief objection to them—viz., the mixture of the liquid with the solid matter—has been met by an improved arrangement to carry off the liquid by a pipe into a pit, where it is filtered, and runs into an overflow drain, or, what is better, is used for irrigation.

The increased use of baths has created

work for plumbers, and the advantages of them in houses are very great. The waste-pipe, if not properly connected, is, however, often a source of evil to the inmates, and in all cases should be taken outside the wall, and turned into a cesspool or gully, so that no direct communication is made with the drain. The most expensive part of a bath is the supply of hot water, and this is accomplished by two or three methods, the simplest being by a gas-stove, or a batten of gas under the bath; but this is by no means an economical plan, as, although the first cost is comparatively trifling, the consumption of gas for this purpose soon amounts to the extra cost of providing a hot-water apparatus. Another plan is, to fix a stove, with boiler, in the bath-room, which is attended with extra trouble; but the plan most economical and easy of use is a wrought-iron boiler fixed at the back of the kitchen-range, and pipes laid to a hot-water cistern in the bath-room. Although the original cost of this plan is the greatest, its first expense is also its last, as the kitchen fire is utilized for heating the boiler.

When opportunity offers, a coil of hot-water pipes should be fixed in the hall or staircase, communicating with the flow-pipe, and the extra expense is very trifling. The advantage of heat in the staircase and passages is almost incalculable; the air entering the rooms, being warmed, produces an equable temperature over the whole house, and the chances of catching cold by coming directly out of a warm room into an air very little above the temperature of the external air is greatly reduced. It is a great convenience in every house to have a supply of soft water for washing; and even in London, where the atmosphere is much purer than formerly, I believe this is practicable. The expense in forming a water-proof tank underground, and laying special drains, has prevented the utilization of rain-water in small houses, but if the greater part of the water from the roof were collected into a cistern inside the house, the cost would be very trifling.

The use of zinc as a roof-covering has lately become far more general than formerly, and when properly laid it has proved itself a useful material and is much cheaper than lead. The ready way in which it can be shaped, and the many uses to which it is capable of being applied, will doubtless greatly increase its demand.

A word or two on drains naturally follows the plumber's work, and on this subject I regret so little advance has been made towards perfection. The glazed earthenware socket-pipe is very well adapted to its purpose, if care in the method of laying could be insured, but the work is usually intrusted to a workman often little better than a laborer, with whom rests the responsibility of laying each pipe to a uniform fall—that the bottom of the trenches are not soft, that the pipes are carefully jointed all round (in nine cases out of ten neglected at the bottom, causing them to drop after they are laid), and that all connections of soil and other pipes are securely made, and, above all, that the drains are properly trapped. All these things are most important, but their position makes it difficult to properly superintend them, and as they are very soon hidden out of sight after they are laid, everything depends on the care and integrity of the workman. A great deal of the complaint of bad smells arises in houses which are supposed to be properly drained, by their faulty laying and connections, and naturally occasions dissatisfaction to all concerned. How to remedy this I know not, except by employing a responsible and independent person whose sole duty it is to do work of this kind, and in case of failure subject to a heavy fine. This is perhaps a novel idea, but as so much of health and possibly life is due to the perfectness of the drains some such plan is desirable, especially as the houses in which the least care is bestowed are often tenanted by persons to whom the want of it proves most fatal. Drains should be kept as far as possible out of the house, and no pipes except the soil-pipe connected with them (and I believe there is a plan whereby this may be prevented, but I do not know the details). All waste-pipes should be carried outside the house into a trapped gully. A ventilating-pipe should be connected with the soil-pipe, and carried well above the roof of the house and clear of all windows; and although this is not altogether effec-

tual, it is a great easement to the drains.

The almost universal use of gas in houses requires special provision, and much of the outcry for increased ventilation arises from its use: so long as rooms were of a moderate height, and candles or oil were the only means of illumination, there was no urgent need for ventilation, but now that the temperature of rooms is so increased by reason of the gas, some method of getting rid of the superfluous heat as well as the impure air should be provided. If instead of the lights branching out from the chandelier they turned inwards from a ring under a kind of glass-trumpet mouth tube communicating with a ventilator, much benefit would arise. As this, however, would alter the style of gasfitting, there would doubtless be an objection to its use; failing this, a hopper in the depth of the floor over a perforated ceiling-flower and a ventilating-pipe carried into the flue of the room above, produces a manifest improvement in the comfort of the room. Rickett's ventilating burner is a very good proof of my suggestion, as wherever it is used it gives great satisfaction. I dare not go further into the subjcet of ventilation, this being a topic sufficient for a special paper, which I trust some one will favor us with during the next session.

A great outcry was raised by some architects against the use of plate glass, and although it seriously affects a design, its advantages are so great that the public are not at all likely to dispense with its use, nor to be content with it in small squares, divided by very heavy sash bars. As a kind of compromise, plate glass is by some used in the lower portion of a window, and painted or tinted glass in ornamental designs in the upper. This arrangement has caused the subject of ornamental glazing to be taken up, and instead of the matted or embossed glass formerly universally used, a good effect is produced by glazing in tinted glass in ornamental patterns, or by slightly painting the glass in such a manner that its transparency is not lost.

A process has lately been invented to render glass non-fragile, and many things are promised by its use, but as the manufacture of toughened glass is in its infancy, very little has, I believe, yet been done of service to the house-builder.

The decorative treatment of iron has been well developed recently. Much of the wrought iron work is really artistic, and the designs for cast iron are, as a rule, adapted to the material rather than as formerly producing in cast iron a design only fitted for wrought iron. Notwithstanding the favor in which graining has been held for a long time, public taste seems now to incline towards ornamental painting, and the effect produced by a room artistically decorated is very pleasing, and far less monotonous to the eye than the repetition of graining. The use of varnish gives the work painted in this way all the advantages that formerly only belonged to grained work.

Design in paper-hangings has lately shown great improvement; instead of patterns of leaves and flowers, and watered satins served up with a few alterations and different colors year by year, some of the best designers in our profession have turned their attention to the subject, and the appreciation of their designs is proved by the fact that old-fashioned patterns are fast giving place to the modern ones. One of the greatest improvements is the use of the dado and frieze as a means of decoration, and as a common-sense way of papering a living-room and stair-case, and with ordinary care in the selection of color, either in complement or contrast, the effect cannot be other than satisfactory. And now, Mr. President and gentlemen, I have worked through the several trades in house-building. I am aware there is much more that I might have brought forward, but I fear that I have already tired you with so much detail; but, as I expressed at the commencement of the paper, my object was to elicit the opinion and experience of those present on the improvements in house-building generally. I now leave the matter in your hands, thanking you for the attention and patience with which you have been pleased to favor me.

THE Settle and Carlisle Railway is seventy-two miles long and has cost £50,000 per mile, or £3,600,000. It has steel rails throughout of 82 lbs. per yard.

EXPERIMENTS ON THE FRICTION BETWEEN WATER AND AIR.

By Dr. RITTER VON LANG.

Proceedings of the Royal Society.

The method adopted for estimating the mutual friction of water and air consisted in connecting a glass tube of eight centims. in length and 0.72 internal diameter with the pipes which supply Vienna with water at a pressure of four atmospheres. Arrangements for securing a vertical position for the tube insure a perfectly continuous jet, devoid of any broken surface; and a glass tube surrounding this jet, with its axis coinciding with that of the jet, acts as an aspirator into and along which air is drawn through a lateral feeding-tube. The amount of this indrawn air corresponding to the fall of a given amount of water was determined by observing the rate at which a film of soap was borne along the feeding-tube; and the velocity of the water causing the indraught was calculated from the diameter of the water column and the quantity of water discharged along it in a given time; but after having once determined the form of the slightly conical water column, the amount of water discharged was the only datum required for the calculation.

The influence of a greater or less section of the air-feeding tube on the volume of the aspirated air was carefully determined, while also the absence of any appreciable retardation due to the soap film was established.

Neglecting the slightly conical character of the surface of the water column, and assuming (as the result of experiments in which the motion of a smoke cloud was observed) that the movement of the air was throughout in lines parallel to the axis of the tube along which it flowed, and showing that the pressure does not vary along the length of the tube, the author proceeds to discuss the hydrodynamic equations expressing the conditions of the problem (the motion of the air being uniform and independent of time), and represents the volume of air A passing through the tube in a second as:

$$A = W\left(\frac{R^2 - r^2}{2r^2\,(\log. R - \log. r} - 1\right),$$

W being the weight of water, in grammes, discharged in a second, r the radius of the jet in turns of the micrometer screw (6.8 turns of which correspond to 1 centim.), R being the radius of the aspirating tube.

The results obtained by observation accorded well with those given by this equation, so long as the value of R did not exceed the limit within which the suppositions regarding the motion of the air hold good.

The question was considered whether the results might not be brought into even closer accord with theory by the assumption that a slipping action takes place between the air and the water-jet on the one hand, and between the air and the tube on the other, instead of the assumption previously made that the air adhered alike to the water and to the tube in its passage. The result of the calculation, however, led to no nearer approximation; and, finally, experiments with other materials for the tube and gases (namely, coal-gas and carbonic anhydride) were made, without resulting in any marked difference from the results obtained with air and gas.

MM. Pierre and Puchot show, says the *Chemical News*, that if commercial hydrochloric acid cooled down to a temperature of 22 deg. Cent.—equivalent to 7½ deg. Fah.—is supersaturated with dry hydrochloric acid gas, an abundant crystallization ensues. These crystals are decomposed on exposure to the air, with the evolution of dense white fumes. In water they dissolve rapidly. Their composition is four equivalents of water to one of hydrochloric acid. The authors claimed to have attained the temperature of—35 deg. Cent. (—31 deg. Fah.) with mixtures of snow and hydrochloric acid, which they recommend as a freezing mixture.

REPORTS OF ENGINEERING SOCIETIES.

THE EIGHTH ANNUAL CONVENTION OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS.

The Convention was called to order by the Chairman, Mr. Thomas C. Clarke. A paper on the "Erection of the Verrugas Bridge," by L. L. Buck, published in the regular proceedings of the society, was presented by Mr. Virgil C. Boge, and received with much interest by the members. G. S. Morison, then presented a paper on the "New Portage Bridge," which was published in the January proceedings. Mr. W. J. McAlpine was then called upon to contribute to the discussion of a paper by Clemens Herschel, upon "Waves of Translation that emanate from a Submerged Orifice," published in the July, 1875, Proceedings of the Society by that gentlemen. Gen. T. G. Ellis made some remarks on the subject.

After this followed a discussion upon Gen. T. G. Ellis's paper on the "Description and Results of Hydraulic Experiments with Large Apertures, at Holyoke, Mass., in 1874," published in the February Proceedings of the Society. Mr. Clemens Herschel offered a few remarks commendatory of the paper. Gen. Ellis then made some remarks upon a criticism of his work published in one of the scientific papers. His remarks demonstrated the extreme care with which his experiments were made, and only added testimony to the great reliability of his results. He even went so far as to carefully find the exact value of the force of gravity at the place where he experimented.

A report of a committee upon an "Uniform System of Gauging Streams" was then submitted by Gen. Ellis, the chairman. The sense of the committee was expressed in the remark that no uniform system could be established, as the method of gauging must be adapted to the conditions of each stream. The report was signed by but two members of the committee of three. Then followed remarks upon "Notes and Suggestions upon the Croton Water Works and Supply for the Future." Mr. J. J. R. Croes stated that it was not safe to depend upon inadequate masonry aqueducts set in embankments where the embankments are depended upon to resist the pressure, as they have all settled and cracked longitudinally throughout great lengths of such conduits. He recounted several instances of these failures, and his opinion was, that the masonry should be strong enough to resist the whole pressure.

The paper entitled "Notes on the Improvement of the Mouth of the Mississippi," by W. M. Roberts, published in the December, 1875, proceedings, was then submitted. Capt. James B. Eades not being present, Mr. E. L. Corthell, First Asst. Eng. So. Pass Jetty Works, gave an account of many interesting matters connected with the work. It was a matter of remark that this was the anniversary of the commencement of the jetty improvement. Mr. Corthell's paper consisted of an extended series of tables showing a great number and variety of very interesting facts connected with the important national work under his superintendence. His remarks showed the great result obtained in one year, and gave rise to a conviction that it is a question of no very long time when we shall possess a magnificent entrance to our greatest river. This great question about which so many theories have been advanced is fast being settled by experiment.

The next paper which was read by the secretary, was upon the same subject by Capt. C. W. Howell, of the U. S. Engineers, showing the failure of the Jetty System, arguing that such would be the case from the facts that have been obtained in the case of certain foreign rivers. A reply to this paper was then made by Col. W. Milnor Roberts, the author of the original paper under discussion. He corrected many of the statements of Captain Howell, and made a forcible reply to that gentleman's paper. He strongly referred to the fact, above noted, that the question of the success of the Jetty System at the Mississippi is fast being settled by experiment and *not* at the expense of the Government.

It was stated that Capt. Eades in the past year had changed the depth upon the Mississippi from seven or eight feet to nearly eighteen feet, and that several of the largest ocean steamers had recently passed in and out. Col. Roberts read an extended and very valuable communication upon the subject of the Mississippi Jetties which he had prepared without reference to the discussion of his paper. This additional paper showed a very extensive and searching knowledge of the subject. He was followed by Gen. J. G. Barnard who was connected with the surveys at the mouths of the Mississsippi almost from the commencement of the agitation for the improvement of the entrance to the river, and for many years afterward. He recounted the history of the Canal Project for accomplishing the object arrived at. He became of the opinion that although a canal might be built, it would not furnish the desired relief. He was satisfied of the greatly superior desirability of an open river mouth. This conviction gained ground among the people till it became evident that it was demanded that the experiment of an open river mouth communication should be tried. Then followed an account of the early efforts in making this kind of improvement. The first was by dredges and was followed by an attempt to build jetties. These efforts were followed by various experiments and theories till the time of the present experiment which gives such hopeful promises of success. The speaker long ago had no doubt that jetties could be constructed and maintained. He contributed some further facts regarding the history of this discussion and then closed.

After a recess of an hour the "Report of the Committee on Tests of American Iron and Steel," W. Sooy Smith, Chairman, was submitted. Mr. Smith appealed to the society to exert itself to secure a suitable appropriation to carry on the test for another year. There were facts cited to prove the *necessity* of a continuance of these experiments, and a statement

was made tending to show that there was a great deal of opposition to this work, that the very existence of the Board was threatened.

Mr. Chester said that he was assured by private information that Congress was much better disposed towards the subject than was imagined, and he therefore moved that means be taken to provide the society with more extended and reliable information about the matter.

Mr. Clemens Herschel reported "On the Metric System of Weights and Measures."

Mr. Coleman Sellers opposed the adoption of the Metric System by compulsion or law, in a well chosen speech and brought forward many facts to support his position. He favored the legalizing of the system, but thought that the pressure for its adoption should come from the people and not be forced upon them.

Prof. J. E. Hilgard, of the Coast Survey, followed Mr. Sellers. He stated that it would be dangerous to the introduction of the System to urge a compulsory law upon Congress. His reason was that it was very difficult to get any attention to the matter from the members of Congress. He believed it was best to use it and teach it as far as we could till those who had learned it should become legislators, when something could be done.

Mr. Herschel offered two resolutions as follows: Resolved that the Society appoint a committee of five to draft a memorial to Congress concerning this matter, and, Resolved that the American Society of Civil Engineers will forward by all legitimate means the adoption of the Metric System in the government offices.

A motion was made by Mr. Chester to vote on these resolutions by letter ballot.

Mr. Robert Briggs and Prof. DeV. Wood, opposed the passage of the motion on the ground of want of discussion. Mr. Herschel urged that the adoption of the motion would favor the most complete information of the individual members upon the subject. Mr. Briggs still opposed the motion. Mr. Chester then withdrew his motion.

A motion was then adopted to appoint a committee of five to consider these resolutions and report at the next Annual Convention.

Here followed a report on Railroad Accounts and Returns by W. P. Shinn, in which was given valuable information and principles of such accounts and returns. He believed that such accounts and returns should be made upon the same principle by all the various roads. He set forth an exceedingly simple and comprehensive set of headings or principles upon which such accounts and returns could be kept. The paper will be found to be of great value to those who desire information upon these matters. A committee was urged for the consideration of the adoption of a uniform system of keeping these accounts and returns and a consultation with State Railroad Commissioners looking to the same end. The appointment of this committee was opposed by Mr. Chas. H. Fisher, Chief Engineer of the N. Y. C. R. R., on the ground that State Railroad Commissioners are regarded as hostile organizations by railroad companies, and that if any thing was done the roads should be consulted.

Mr. Chas. Latimer, Chief Engineer of the Atlantic and Great Western, gave a statement of his method of keeping such returns which was of a very satisfactory nature and surprisingly complete, whilst very simple.

Mr. Ashbel Welch gave an additional report on the "Form, Weight, Manufacture and Life of Rails." He set forth some interesting experience on the line between Philadelphia and New York where rails had withstood excessive use for a great time. The report was accepted.

The report on the Nomenclature and Classification of Masonry by J. J. R. Croes told of progress made, and urged more general assistance and replies from the members. Adopted.

Gen. T. G. Ellis read the report of the Committee on the Failure of the Worcester Dam, Mass. The dam failed because of leakages and their gradual increase, till they at last rapidly undermined the works, causing them to cave in and break down in large masses. Accepted.

Mr. Wm. J. McAlpine followed with some remarks and promised a communication in which should be set forth the facts which he has collected in his work of restoring the dam and rebuilding it.

The Report on the Resistances of Railway Trains was read by Mr. Wm. P. Shinn, which consisted of a communication from Mr. P. H. Dudley, of the L. S. & M. S. R. R., on his experiments with the Dynograph. These were very careful experiments but the communication, though of usual length, was only long enough to create a desire for further information from the same source.

Mr. Chas. H. Fisher moved the immediate printing of the communication of Mr. Dudley, and that it be circulated amongst the members, which motion was adopted.

Mr. W. Milnor Roberts moved a graceful tribute of thanks to the Philadelphia members for their numerous courtesies. Also to the Judges of the Centennial for the use of their hall, and to the Chairman, who so successfully and acceptably presided at the meetings.

An excursion by members of the society was made on June 16th over the New York & Philadelphia New Line R. R.

The American Institute of Mining Engineers.

The first meeting of the convention of this body took place in Philadelphia on the evening of June 20th, at the Franklin Institute, Mr. Holley, President, in the chair.

FIRST DAY—TUESDAY, JUNE 20.

The chairman introduced Mr. Franklin B. Gowen, President of the Reading Railroad, who welcomed the members to the city in an address in which he called attention to the great waste attending the present method of mining and preparing coal for market. Great piles of the purest carbon in the shape of coal dust lie near the mines, and their presence and character may possibly puzzle the future geologist. He explained a recent method in-

vented by Mr. Wootten for utilizing this waste in making steam in stationary engines. After a trial of several months with stationary and locomotive engines he believed they had obtained results equal to those obtained from the most expensive coal.

There are at least forty million tons of this material lying useless in the anthracite regions. He threw out the suggestion that this material could be used in reverberatory furnaces in melting iron. The prosperity of this city is dependent upon the mining interests of the State of Pennsylvania. The time has gone by for the idea that practical men alone are required to develop these interests; there is needed also high scientific attainments such as this Institute represents.

The chairman announced the election as President of the Institute for the coming year of Mr. Abram S. Hewitt, whom he introduced.

The President-elect then addressed the convention. He gave a history of the progress of mining engineering and the developments of the metals during the last hundred years. The first pig iron made from American ore was smelted in England in 1608. In 1702 the first furnace was built at Pembroke, Mass. The total export of iron in 1717 was three tons; in 1771 it had increased to 7,525 tons. The production of coal in the year 1874 in Great Britain amounted to 46.4 of the whole product of the world; in the United States, 18.4. In the same year the production of iron in Great Britain was 45.2, and in the United States 18.1 of the whole product. This shows that the production of coal and iron in any country generally bear the same relations to each other.

The leading facts in the mining history of the country may be enumerated as follows: First, the erection in Centre Square, Philadelphia, of the first steam-engine ever built in America; in a hundred years steam has transformed the face of the earth; second, gold mining in the South in the early part of the century; third, the opening of the anthracite coal fields and the use of anthracite in blast furnaces; fourth, the use of raw bituminous coal in the blast furnace; fifth, the development of the copper mines in Lake Superior; sixth, the discovery of gold in California in 1848, or rather its re-discovery; seventh, the commencement of quick-silver mining in 1851; eighth, the introduction of the Bessemer steel process; ninth, the commencement of hydraulic gold mining; tenth, the commencement of iron mining in the Lake Superior region; and eleventh, the discovery of silver in the Comstock lode, which opened an era of speculation which has hardly ceased since that time.

He concluded his address by a review of the situation in the coal region, with suggestions as how to harmonize the relations of the employers and employed.

SECOND DAY—WEDNESDAY, JUNE 21.

The convention of Mining Engineers reassembled Wednesday morning at Judges' Hall, Centennial Grounds, Mr. Holley in the chair. There were present a large number of scientific gentlemen from this and other countries, including Prof. Joseph Henry, of the Smithsonian Institute, Isaac Lowthian Bell, M.P., F. R. S., a distinguished iron-master of England, and Dr. Wedding, member of the German Cabinet and Commissioner of Mining.

The entire session was occupied in the reading of a long and valuable paper on "The Theory of the Action of the Hot Blast," by I. Lowthian Bell, of England.

THIRD DAY—FRIDAY, JUNE 23.

Prof. G. C. Brodhead, State Geologist of Missouri, read a paper on the lead deposits of Southeast Missouri. The paper dealt principally with the percentage of galena in the various qualities of ore. The lead district covers an area of over 3,000 square miles.

Mr. Oliver Evans Woods, descendant of Oliver Evans, read some original documents relating to the early use of anthracite coal in the smelting of iron. These papers were in the form of affidavits of witnesses to Evans's experiments.

April 5, 1806, they witnessed an experiment of introducing air at a high pressure into the furnace. April 7, 1806, Evans made a public experiment of melting iron with Lehigh coal, which, it is asserted, is the earliest date at which raw anthracite coal was ever used for that purpose. February 11, 1808, a public experiment was made of blowing a steam blast into the furnace, the furnace being closed at the top, with a heavy cover and a valve, which, when the pressure reached a certain point, would let out the gases. The idea expressed in the paper was, that the steam would be decomposed in the furnace, and furnish a greater amount of oxygen than atmospheric air, and in this way great economy would result.

Dr. Wedding, of Germany, made a few remarks on the advisability of adopting a uniform nomenclature for the various qualities of iron, which should be used in common by the four great iron-producing nations—America, England, Germany and Sweden. Under the present system it is almost impossible to understand any scientific article because the quality of the iron can not be known from its name. For instance, the word steel, as used in America, has an entirely different signification from the "stahl" of Germany, which means literally anything that can be hardened. There are three conditions of iron which ought to be definitely known by universal names: first, the iron from the blast furnace, which, in the process of smelting, takes up too much carbon; second, the metal, after it has passed through the different processes used in abstracting this carbon, like the Bessemer process; and thirdly, the metal which has passed through the carbonizing process. He suggested suitable terms for these three conditions of iron.

Messrs. Firmstone, of the Glendon Iron Works, and Reese, of Pittsburgh, saw no objection to the terms used, but thought that trouble would arise in getting rid of the terms now employed.

Mr. Egleston, of the School of Mines, thought, while so many representatives of the iron interests of the four countries were

present in the city, that an international committee should be appointed to consider the matter, and made a motion to that effect, which was carried.

Mr. Holley, President, liked Dr. Wedding's theory, and suggested the three terms—"bloom metal," "piled metal," and "ingot metal." To this Dr. Wedding was agreed in respect to the first and last, but could not admit "piled metal," which would not in all cases describe it.

Dr. Egleston made a few remarks on a recent accidental discovery, made in the School of Mines, of the character of Lake Superior iron. It had been discovered that boracic acid was to be found in it, and tests were being made to find the metal boron, which would account for the peculiarity of this iron.

Prof. J. S. Newberry, State Geologist of Ohio, read a paper on the "Black Band Ore of Ohio." This ore is in the form of a carboniferous shale, which contains about 25 per cent. of carbon, and after calcination about 52 per cent. of iron. It is similar and almost identical with the black band ore of Scotland, from which the well-known Scotch pig iron is produced. It is found in two sections of Ohio, the Mahoning Valley and the Tuscarawas region, and these are the only known mines in this country. The quality of metal is unsurpassed, and the ore lies in beds averaging ten feet deep, where they are easily worked.

R. W. Hunt, of the Troy Steel Works, read an interesting historical account of the introduction of the Bessemer steel process into this country, and its subsequent improvement, until now there are twelve Bessemer steel plants, which turn out a greater quantity than is made in any other country. He paid a deserved compliment to Mr. Holley, the President, who was foremost in these improvements, and to whose genius the successful prosecution of the manufacture was mainly due.

Mr. Pearse, of Harrisburg, called attention to the fact that the late J. Edgar Thomson was an early advocate of the new process, and had made all necessary arrangements for introducing it when Mr. Holley secured the patents. It was through him that the Pennsylvania Railroad Company became the apostle of the new steel in this country, and broke down the prejudices in the minds of railroad men against it.

The first paper read at the afternoon session was on the subject of the "Manufacture of Iron Rails," by W. E. C. Coxe, Superintendent of the Reading Railroad Iron Works. He stated that, in 1866, the Reading Railroad Company determined to manufacture their own rails, so as to secure the best possible rail for use on their tracks. In that year a great variety of rails were used, some of which lasted only six weeks. The works were completed and put into operation in 1868. Nine thousand tons of these were laid in 1868, of which, at the end of 1875, only 50 per cent. had been removed from the tracks. It was evident, after a short trial, that the Company saved money, not only in the first cost of the rails, but, what is more important, in the cost of repairs.

A discussion then took place on the paper of I. Lowthian Bell, on the theory of the hot blast. So few could hear the paper when it was read in Judges' Hall that there was a general desire to postpone discussion until the paper was in print.

Mr. Bell gave a resumé of the paper, laying special stress upon the point that the action of the blast furnace was a chemical one. By his experiments he had found that when he got to a certain composition of the gases further action ceased. Fully one-seventh of all the pig iron produced in the world is made in England alone with the hot blast. He was willing to believe some things which he could not understand; one was that he had often heard in this country that the hot blast would not produce good car-wheel iron.

Mr. Firmstone said he believed the reason for this was, because with the hot blast a greater amount of silicon was left in the iron. It was a fact that ores that would make good car-wheel iron with cold blast would not do so with the hot blast.

Dr. Wedding gave a theory of his own as to the effect of raising the temperature above a certain point in the furnace; he had, however, abandoned it since Mr. Bell's experiments with the furnace itself, and agreed with that gentlemen in his conclusions.

Mr. L. A. Riley gave the results of his observations in boring with the diamond drill in exploring the coal fields, giving the cost of such explorations.

Mr. J. B. Britton, of the Ironmasters' Laboratory, read a paper on the composition of flue deposits. He gave the results of several analyses from the flues of different iron furnaces, showing that a large amount of phosphorous was volatilized and expelled from the blast furnace, as well as large amounts of soda and potash. These deposits have been found to be of great value as fertilizers.

Mr. H. S. Munroe, of Portland, read a paper on the extent and nature of the coal fields of Japan. The early estimate of the mineral wealth of Japan was a very erroneous one. Gold was supposed to exist in great abundance; this is not the fact; the most valuable mineral found is coal. The coal yield in 1874 was 436,800 tons, and is increasing annually; it will probably become an important element of wealth. All kinds of fossil fuel are found. The coal deposits are of recent origin, and resemble brown coal. The limit of workable coal is about two feet.

At the evening session, Mr. Julian Deby, of Belgium, read a paper on the process of sinking deep shafts. He said he would have illustrated his remarks, but he had been unable, after six weeks' endeavor, to get his drawings out of the Custom House in New York on account of some alleged informality in the papers. The difficulty to be surmounted in sinking mining shafts below the water level is to get a tubing strong enough to sustain the outside pressure. Mr. Chaudron, a Belgian Engineer, finally solved it by constructing a tube of cast iron in sections with flanges, each

section being thoroughly tested with hydraulic pressure. The advantages of this system are the complete isolation of the water from all the workings; the durability of the shafting; the great diminution in the cost of sinking the shaft; the obviation of any necessity for pumping machinery during the boring and nearly so afterwards; the greater degree of comfort to the miner by the absence of water and the possibility of traversing any number of water levels irrespective of the amount of water they contain.

Mr. F. L. Clerc read a paper on a new process of spelter manufacture, which promises to secure a greater percentage of metal than the processes now in use.

Mr. O. J. Heinrich read a paper on an explosion of fire damp in the Midlothian Colliery, Virginia.

On Saturday the convention will make an excursion over the Reading and Lehigh Valley Railroads, as far as Bethlehem, and will inspect the steel works at that place.

FOURTH DAY—MONDAY, JUNE 26.

Mr. J. B. Pearse, Secretary of the State Geological Survey, read a paper on the "Early History of the Iron Trade in this Country."

Prof. Persifor Frazer, Jr., read a paper on the iron ores in the new red sandstone in York and Adams counties, in which he gave the results of his explorations in the geological survey of that section. The great peculiarity of these deposits of iron on the new red sandstone is that the softer iron is protected from erosion by walls of trap. These specular and micaceous ores are found just at the edges of the new red sandstone, where it is very thin.

Mr. Bramwell, Superintent of the Quinnimont Furnace, Virginia, read a paper on the partial renewal of a furnace while in blast.

Mr. C. H. Vannier read a paper on the process of roasting sulphurous ores in New Jersey.

Mr. J. Blodget Britton read a paper detailing experiments made by him for determining the amount of water in coal.

At the afternoon session, Mr. C. R. Boyd, Jr., of Wytheville, Va., read a paper on the ores of Southwestern Virginia.

Mr. H. S. Drinker made a few remarks on the progress of the Sutro Tunnel.

The chair appointed as a committee on the nomenclature of iron the following gentlemen: Mr. Akerman, of Sweden; Mr. Bell, of England; Mr. Gruner, of France; Mr. Turner, of Austria; Dr. Wedding, of Germany; Messrs. Egleston and Holley, of the United States.

At the evening session Mr. Holley presided. The first paper was by Prof. Adolph Henri, on "The Manufacture of Forged Car Wheels." His translation having been delayed, he read the paper in French. He illustrated the method of manufacture by many illustrations on the black-board. He stated that no wheel manufactured by this process had ever broken.

Mr A. S. Munroe read a paper on the metallic deposits of Japan.

Professor Persifor Frazer, Jr., explained the results of his investigation into the igneous rocks, commonly known as trap rocks, which he illustrated with the lantern.

A resolution of thanks to the retiring President, Mr. Holley, for his successful management during the past year was passed, after which the Institute adjourned until the 3d Tuesday in October.—*The Bulletin.*

IRON AND STEEL NOTES.

IMPORTANT DISCOVERY IN THE STEEL MANUFACTURE.—Mr. H. Augustus Guy, of the firm of Messrs. H. Augustus Guy & Co., has, under the title of "invincible," introduced a new variety of steel, tempered by a novel process, and which has been found peculiarly fitted for the manufacture of turning tools in which a high degree of toughness and hardness is essential. Besides the great saving which must follow from the lasting quality of this material, considerable freedom from danger to machinery and to those employed in working it must necessarily be secured by the employment of a reliable homogeneous metal in situations where resistance to great strain is required. That the "invincible tool steel" fulfills all necessary conditions may be assumed from the very satisfactory result of a series of searching and thoroughly practical trials upon the best of all crucial tests, viz., the steel tires of the leading makers. A pair of $1\frac{3}{4}$ square tools on Charles Cammell & Co.'s 5-foot tires may be taken as a specimen. The cut was $\frac{3}{8}$, and the feed 7 to the inch. Each tire was finished in one hour and thirty-five minutes; the points of both tools were quite perfect; and the same tools, without any repairs or grinding, afterwards turned another pair of 5-foot tires by the same makers under similar conditions, and in about the same time. Each tool being then simply ground up, not re-made and tempered, was put upon a pair of Taylor Brothers' 5-foot tires. The one tire was completely turned in two hours and seventeen minutes, and the other in two hours and twenty minutes, after which the points were perfect; and without even sharpening, turned a pair of Charles Cammell & Co.'s 5-foot tires in about one hour and thirty minutes each tire. The cutting edges were but slightly impaired. The trials we have mentioned are only an example of nearly two months' continuous work upon the hardest tires in use, and we have no doubt that those firms who use steel for turning purposes, are necessarily deeply interested in its economy, will find the "invincible steel," despite its nominal high cost, by far the most economical turning steel yet discovered. We are glad to note that Mr. Guy, the inventor, has had the courage to analyse the criticisms which many leading authorities have, by the actual use of steel, candidly expressed, and the result is, that the steel, as now made, is worthy of its high claims, and substantially deserves the invincibility indicated by its name.

PRODUCTION OF BESSEMER STEEL IN THE WORLD.—In the *Moniteur des Interets Materials*, in an article taking into consideration the present state of the Bessemer steel manu-

facture, the following summary of the establishments now in existence for its production is given: Great Britain is put down on the list as possessing 21 Bessemer steel works, containing 105 converters; Prussia, 14, with 61 converters; Austria, 12, with 30 converters; Bavaria, 2, with 4 converters; Saxony, 1, with 4 converters; Alsace, 1, with 2 converters; France, 8, with 25 converters; and the United States, 8, with 16 converters; making a total of 67 establishments, containing 247 converters, which, collectively, are estimated as capable of turning out, if required, as high a make as 2,500,000 tons of Bessemer steel per annum. Curiously enough, we do not find Belgium mentioned in this list, although she possesses at least two, if not more, Bessemer steel works, and in like manner both Sweden and Russia have been omitted in this enumeration, although both these countries possess Bessemer steel works of considerable importance.

RAILWAY NOTES.

RAILROAD PROGRESS IN PERU.—Mr. Henry Meiggs has submitted to the Peruvian Government a proposition for a new contract. He offers to build, in three years from the date of the contract, the unfinished section of the Lima & Oroya road to the Oroya, and further, to extend it from that point to the great silver mines of Cerro de Pasco; also to build a tunnel which shall drain those mines very much below the level of the present drainage tunnel, which now limits the working. In return he asks to receive, according to Peruvian mining law, the right to the body of ore between the present lowest tunnel at Cerro de Pasco and the proposed new tunnel; also the right to enter and possess the abandoned and worked out mines there and such new ones as have been and may be discovered on the line of the Oroya Railroad and its proposed extension.

THE FIRST RAILWAY IN CHINA.—A little railway is being laid down between Shanghai and Woosung—a town at the junction of the river Hwang-poo (on which Shanghai is situated) with the Yangtzee. The distance is only nine miles, but the great object is to establish a railway of some kind on Chinese soil, in order to show the people what it is like. The land was quietly bought up by a few foreign merchants, the roadway leveled, and a company subsequently formed to carry out the undertaking. A large portion of the required capital was subscribed in England, and the remainder in Shanghai. The mandarins have been all along jealous of the proceedings of the company, and are doing their best to embarrass it, but the rest are perfectly well disposed. They often come to look at it, and only yesterday (says a Shanghai correspondent of *The Times*, writing on March 23d,) several very respectably-dressed Chinese, who had come for the purpose, were invited to ride in the ballast-trucks. They were a little timid at first, but eventually accepted the offer, and were delighted with the experience. The engine which is being used is only of two or three horse-power, and hardly bigger than a good-sized Newfoundland dog. The Chinese are employing an English engineer, Mr. Tyzack, and English machinery, in an experimental opening-up of the coal mines of Kelung, North Formosa.

LOCOMOTIVE TRIALS.—From the letter of a correspondent we gather the following account of a comparative test of locomotives on the Boston and Albany Railroad: Now that the railroads throughout the country are reducing their tariffs on freight, it becomes a matter of some importance to know what particular construction of locomotive engine will do the required work, and with the least expense to the corporation. There seems to be a difference of opinion existing among master mechanics as to the comparative merits of the engines known as Mogul's, constructed with three pair of drivers connected, and pony truck, and the ordinary two pair of drivers and single truck. Without going into any lengthy detail as to either, I wish to lay before you some facts which may interest many readers of the magazine. The officers of the Boston and Albany Railroad have given this matter their attention, and have for the five days as specified in the table below, thoroughly tested the economy and relative merits of the two engines. The trial was from Albany to Pittsfield and return, a distance of 101 miles, between the Mogul engine "Brown" No. 230, built for the company by the Rhode Island Locomotive Works, and the "Virginia" No. 11, built at the shops of the company at Springfield, by Wilson Eddy, master mechanic; each engine pulling the same number of loaded cars; and as you will see below, demonstrated conclusively the great economy of the "Virginia" over the Mogul engine "Brown," and a saving to the corporation in five days of $24.24 or in the ratio of $1,518.05 per year on fuel. This certainly, so far as this road goes, does not speak favorably for the Mogul engines. What the tests are upon other roads I have yet to learn.

Performance of Engines at E. Albany.	*Brown* 230. *Coal.* lbs.	*Virginia* 11. *Coal.* lbs.	*Dif.* *Coal.* lbs.
June 16th, 1876.....	6,260	4,800	1,460
" 17th, "	5,930	4,964	966
" 19th, "	6,620	4,900	1,720
" 20th, "	5,980	4,780	1,200
" 21st, "	6,060	4,480	1,580
	30,850	23,924	6,926
Value at $7 per ton.	$107 97	$83 73	$24 24
Cost per mile.....	21 38	16 58	4 80
Cost per trip.....	21 59	16 74	4 85
Cost for 313 trips (year).....	6,759 67	5,239 62	1,518 05

ENGINEERING STRUCTURES.

THE CHANNEL TUNNEL.—A letter from Boulogne gives some details of the operations which are being carried on preliminary to the sinking of driftways for the Channel Tunnel. The writer says:—As soon as the concession was voted operations commenced

in earnest, the interval having been occupied in completing details. From the second week in August to the end of September, the *Pearl*, with her staff of engineers, went out when the weather permitted. M. Larousse, the hydrographer, used to take the steamer to her station for commencing soundings, and ascertained her position by cross-bearings; this being done, Messrs. Potier and De Lapparent, jointly or singly, took an exact register of the depth and time of each sounding, and examined each specimen brought from the bottom, which was put into a specially prepared bottle with a register number. These specimens were sent to Paris, where they were subjected to a more minute examination and classified. M. Larousse took bearings every five to ten minutes to ascertain the steamer's exact position, such continual observation being necessary owing to the ever-varying currents. On days when rough weather would not allow of accurate soundings, or thick weather hid the coast, Messrs. Potier and De Lapparent used to examine the cliffs. During the six weeks' operations 1,522 soundings and 753 specimens of the bottom were obtained; 335 of them have been classified with certainty. The average daily castings of the lead were 70. The boundary line of chalky stratum has been ascertained by the lead bringing up either sandstone or clay, which form the strata on either side of the chalk, and this over a distance of 28 kilometers from the French coast, at which point English waters begin, and the consent of the English Government, in this case a mere formality, was necessary previous to making surveys, which permission has been lately granted. Last autumn's observations and soundings have settled two points—firstly, that no break exists in that portion of the layer of chalk, gault, and *craie de Rouen* which comes to the surface on the bottom of the Channel in the parts where soundings were taken; and, secondly, that the dip observed in some of the strata nowhere exceeds ten per cent. This year's soundings will probably be undertaken from Dover, as being closer to the scene of operation. The belt of sound ings, which is from one to five miles broad, has been made from two to four miles west of the line where the tunnel is intended to be made. For the information of non-geologists it may be explained that the soundings have been made over that part of the Channel where the chalk crops up, and the distance of two to four miles further east is to allow the stratum to dip sufficiently to allow of there being a good thickness between the crown of the tunnel and the bottom of the Channel.

The programme for this year's campaign is —firstly, a series of soundings very close together in English waters to settle a doubt as to whether a divergence of the chalk towards the north is due to a break or is only a dip; secondly, a series of soundings over the projected line of tunnel to ascertain whether the stratum called by the geologist Phillips "chalk with numerous flints," and which overlays the stratum through which the tunnel is to be cut, comes to the surface; thirdly, a series of soundings over the space between those made over the bed of chalk last year and those taken over the line of tunnel; fourthly, soundings over any spaces not already examined; fifthly, boring on shore in the immediate neighborhood of Sangatte, which shall be sunk at least ten meters beneath the gault. When those works have been accomplished a well will be sunk and a heading driven under the Channel. Sir John Hawkshaw's searches are against the existence of interruption of the strata, and confirm the general opinion of geologists that no important flaw exists.

Over that portion of the Channel sounded last year it has been found that the shore slopes regularly and gradually towards mid-Channel, where there is a zone of from fifty to sixty meters, whence there is a gradual ascent to the English shore; the greatest depth is in a few hollows on a line from Blanc Nez to Folkestone, where the soundings give sixty to sixty-five meters; preliminary soundings taken 200 to 300 meters apart over the projected line of tunnel nowhere exceed fifty-four meters.

Before describing the boring at Sangatte it may be borne in mind that two previous series of experiments are on record. The first was the attempt made to supply Calais with water by means of an artesian well in 1845–8; it reached a depth of 1,200 feet, when the rods broke in the green sand and could not be extracted. The only point to the present purpose is that throughout the chalk only spring water was met with, and nowhere in sufficient quantity to rise to the level of Calais market place. The second set of experiments was undertaken by Sir John Hawkshaw, who selected for his Channel Tunnel borings a spot intermediate between Calais and Sangatte, upon La Ferme Mouron, close to Les Barraques. Its chief results tally with the observations taken by Messrs. Mulot Pere et Fils at Calais, the strata only increasing in thickness westward. The daily progress of the borings, through the upper strata, averaged from fifty to sixty centimeters; since reaching the gray chalk (*craie de Rouen*), the rate has increased from 82 to 100 centimeters daily; the greatest progress made in any single day was two meters fifty centimeters in twenty-two hours. Now that a softer stratum has been reached progress will be more rapid.

The correspondent of the *Manchester Guardian* says that a convention was signed last week by the following gentlemen, who have been appointed Commissioners to settle all international questions arising out of the construction of the tunnel:—MM. Gavare, Kleitz, and Lapparent on behalf of France, and Messrs. Kennedy, H. Watson, and Captain Tyler on behalf of England. It is difficult to enumerate all the duties which will come under their notice; but, apart from matters pertaining to the construction of the tunnel, some of their functions will not be unlike those which have to be undertaken by commissioners who are usually appointed in the settlement of boundary and frontier questions.

ORDNANCE AND NAVAL.

IRON *v.* WOODEN SHIPS.—Is an iron-built ship more liable to receive damage on taking

the ground than a vessel constructed of wood? This problem seems to have engaged considerable attention in the United States, and the conclusion arrived at by the Council of the Underwriters' Association is, that vessels wholly built of iron are unsafe risks unless they are exteriorly sheathed with wood. This will astonish engineers and shipbuilders in this country, says the *Shipping and Mercantile Gazette*, who have so long insisted upon the inferiority of wood as a building material when compared with metal.

The late Mr. Grantham in his book on "Iron Shipbuilding," claims especially for iron that a properly built ship will bear greater strains than one constructed of wood. In Fairbairn's work, tables of results are given from actual experiments, and it is shown that a wrought-iron plate only three-quarters of an inch thick is able to resist a force equal to that required in the rupture of a 3-inch oak plank. The strength of dry English oak to resist a crushing force is 4.24 tons to the square inch, whereas wrought iron requires a pressure of about 31 tons to the square inch. The resistance of wrought iron plates to a force calculated to burst them follows a law different to that of oak, the resistance being directly as the depth, and of the latter as the square of the depth. It has been held by several writers that an iron-built ship will bear a greater strain than a wooden-built one when the hull is resting on unequal ground.

The timber joints of a ship are not united either longitudinally, vertically, or transversely, and the strength depends upon the sheathing, which is attached to the ribs, whereas the plating of an iron vessel is made homogeneous by the riveting and laps. When the *Great Britain* was exposed for a whole winter to the action of the sea, stranded in Dundrum Bay, the advocates of iron instanced the case as a proof of the value of the vessel with a metal bottom to resist contact. Another ship was put to rather a severe test on the 7th of April last, when Malta was *en fete* for the Prince of Wales. The Indus, with the outward Indian and Australian mails, when nearing the island, bumped several times on the Monsciar Reef, at the extremity of St. Thomas's Point, remained fast by her heel for some time, but eventually swung round and got off. St. Elmo Light was established to guard vessels from running on to that dangerous reef, but a magnesium light, it is said, caused the mate to mistake his position. The ship, however, having called at Malta, proceeded.

There has been an almost unanimous chorus in favor of iron for shipbuilding, partly from its alleged immunity from breaking when resting on uneven ground. There have, however, been recorded instances of iron-built ships snapping in two directly they struck, and it was said of the *Royal Charter* that "she broke like a tobacco-pipe." The weight of the boilers and machinery must always prove a source of danger to either iron or wooden-built ships, because the mass, when receiving a sudden jerk, will exercise its force on the frames, keelsons, and plating. The boilers, furnaces, and bedding-plates are not compactly stowed like cargo in a ship's hold, but are to a great extent held in suspension, and the dead weight, when brought down as a hammer on the hull, by the vessel striking, is bound to exert its influence. There have been persons in England, however, who have expressed an opinion in favor of wooden steamers in resisting strains on being left dry at low water, or on striking on shoals.

The American Underwriter's Association have turned their attention more particularly to lake navigation, where iron-built screw steamers have very much increased within the past few years; and to obtain greater security from the dangers arising in passing through canals or rivers, the following, among other rules, has been issued:—"Steam-vessels built of iron, not less substantially than required by the Rules of the New York Record for the highest class, but, in addition, having their bottoms built as solidly and defensively as those of modern steam vessels, being timber-filled between the frame of the floor, the filling in whole length well fastened to the floor-plates, the bottom outside planked with wood to the top of the bilge, the planks of three-fourths the thickness required for wooden vessels, single fastened and properly caulked, with water-tight ceiling to the top of the bilge, and three or more compartment bulkheads well caulked, shall be eligible to the grades of the first class for lake navigation. Iron vessels inferior to the above standard of strength and preparation for taking the bottom, to be assigned a grade in the second or third class only."

All iron-built steamers plying on freshwater rivers or lakes would, by this regulation, have to be sheathed outside with wood and filled up inside with timber. The pretentious claims of iron-ships, it is said, have been found out, and now they are in consequence discredited. Iron when covered with wood cannot be efficiently protected from leakage; therefore, if the plates both inside and outside cannot be got at to coat with paint, wherever water insinuates itself decay will be going on by corrosion. If this rule of classification is acted upon by underwriters a great blow will be inflicted upon the building of iron ships in Canada and the United States. Iron-built paddle wheel and screw vessels have been introduced on the Mississippi and other rivers most successfully, and, so far as experience goes, they are worked more economically than wooden-built steamers. The extra weight of hull caused by the wood which the iron would have to carry is a serious objection; the displacement being increased, the consumption would be augmented proportionately. The Committee of Lloyds' Register have never attempted to make the owners of iron-built river, lake and coasting steamers double the bottom of their vessels by wooden sheathing. They require all iron ships to be closely ceiled from the main keelson to the upper part of the bilges, and from there upwards with either batten and space or close ceiling. By rule thirty-five, also the frames and plating of the bottom of all vessels in the upper part of the bilges have to be thickly and efficiently covered with Portland

or other approved cement, mixed with sand, to the satisfaction of the surveyors.

The shipowning interests are opposed to this addition of so many tons of material on the hulls of their vessels, submerging them a foot or more, and the subject is receiving considerable discussion in Canada and the States. Numerous letters and fly-sheets have been published, and among the contributors to the controversy is Mr. D. Bell, of Buffalo, who supplies statistics relating to the iron-built propellers belonging to that port. Action was taken against iron steamers because of the loss of the *Merchant* (iron), last year. This vessel was built in 1862, and her owners had never made any claim on the underwriters until she was lost at Racine. During her existence of thirteen years her owners paid £30,907 on insurance of hull and eastward cargo, and recovered from the underwriters £28,783. The insurers also received about £6,000 on policies for westward cargoes. The ship returned in gross premiums to the underwriters a profit of £7,125 according to this representation. Ten other iron steamers now in existence, and built at a cost of £320,000, are mentioned, and, including the *Merchant*, eleven vessels in all, the sums paid to underwriters were £188,046, and recovered underclaims £79,025, leaving as the gain to the insurers £109,012. This is the practical experience elicited, in an underwriting point of view, on the losses and gains in the working of eleven iron-built steamers in lake navigation. The underwriters say that their earnings do not correspond with the risks undertaken, and the shipowners declare that, if they had been their own insurers, they might have added five new ships to their fleet. The underwriters, on the other hand, draw a distinction between premiums on ships and premiums on cargo, and say that, taking the premiums on the vessels and freight money only, the consideration is too small, and that further protection is needed. Shipowners, it would seem, take the premiums as a whole, and the underwriters look at them in detail.

BOOK NOTICES.

TABLES FOR FACILITATING THE CALCULATION OF EVERY DETAIL IN CONNECTION WITH EARTHEN AND MASONRY DAMS. By R. C. ANDERSON, C. E. London: Henry S. King & Co. 1876. For sale by Van Nostrand. Price $21.00.

In the preface to the foregoing the author complains that though tables have long existed suitable for the calculation of earthwork in the construction of railways, "there are none extant as yet to assist the hydraulic engineer in the infinitely more tedious calculations connected with earthen and masonry dams." This may seem strange, considering the lateness of the introduction of railways and the easiness of the formation of dams, especially for the constructions of tanks in India; but it is, nevertheless, true that though rules exist, tables calculated ready to save time are meagre, and give small help. Here, however, Mr. Anderson, comes to our aid with rules and tables; the latter calculated to six places of decimals and very clearly printed in old-fashioned figures on a very tough paper. There is no country like India for the testing of such earthworks, and perhaps no other man has had better opportunities than our author for reducing his formulae to practice. Not only so, but the work has been printed at Roorkee under the author's superintendence, which adds greatly to its value, and enables us to commend it to the notice of those of our readers interested in damwork in general.

THE FATIGUE OF METALS UNDER REPEATED STRAINS. From the German of Ludwig Spangenberg. Van Nostrand's Science Series No. 23. New York: D. Van Nostrand. Price 50 cts.

Readers of the magazine are already familiar with this record of valuable experiments under the title of Behavior of Metals, etc. All interested in the effects of continuous or intermittent strains in metals of any kind used in construction, should become acquainted with the facts evolved by the patient and intelligent labors of the German engineers.

The results prominently set forth by this record of experiments are thus explained by Mr. S. H. Shreve, C. E., in a preface.

The results of Wohler's very important experiments have been before the profession for some years, but, strange to say, seem to have attracted no attention; and tests of iron and steel still go on for the purpose of determining their elasticity, their elongation under strain, their ultimate strength and other qualities, while Wohler and Spangenberg's experiments show that it is very doubtful that these bear any proportion to the durability of the metals.

These experiments prove that there is a limit of strain within which iron is practically indestructible, and that that limit is but little over 30,000 lbs. per square inch for the best iron. If, as in some of the braces of the Warren truss, and other forms, there is both tension and compression at different times, the limit is the sum of the two strains. They further show the dangerous character of truss work when there is ambiguity of strains. It is to be hoped that the translation of Spangenberg's book will excite sufficient interest to lead to a continuation of these experiments in this country.

ELEMENTS OF PHYSICAL MANIPULATION. By PROF. EDWARD C. PICKERING. Part II. New York: Hurd & Houghton. For sale by Van Nostrand. Price $2.00.

The first part of this excellent work is already well known to students and experimenters in physics.

The topics included in the new volume are Electricity, Heat, Mechanical Engineering, Meteorology, Practical Astronomy and Lantern Projections. There are also some appendices of tables and of directions for management of Physical Laboratories.

No teacher of physics can afford to be without this valuable work of Prof. Pickering. Whether the teacher be naturally ingenious or not, he will derive much valuable aid from the published notes of an experienced physicist, who has had for years a complete outfit of

scientific apparatus at command, and who has moreover made a specialty of instructing novices in the art of experimenting.

Aside from the value of the instruction about how to use physical instruments, the book is valuable for its suggestions as to what to get for the purposes of instruction.

Each section is divided into two parts, a description of the apparatus, and the details of the experiment; the first is designed mainly for the instructor, and the second for the student.

It will be observed from the list of topics that at least two of them are rarely counted as belonging to a course of Physics; these are Mechanical Engineering and Astronomy. No one can object to the expansion of the volume by the addition of those two topics. The excellence of the suggestions renders them the most valuable portions of the book to a large class of students.

The illustrations of the work, although not marvels of pictorial art, are numerous enough and good enough to convey a clear meaning of the text.

A Practical Treatise on Roads, Streets, and Pavements. By Q. A. Gillmore, A.M. D. Van Nostrand, New York. Price $2.00.

Major-General Gillmore is perhaps best known as the engineer officer who so ably conducted the attack on Charleston during the American war. The operations of that memorable siege he described in one of the most graphic and elegantly written works ever compiled by a military man. "The Siege of Charleston" at once raised General Gillmore to a high position in the literary world. His career supplies an excellent example of the strange conditions of life called into existence by the outbreak of civil war in a peaceful nation. General Gillmore appears, by nature, to have been better fitted for the career of a civil than a military engineer; and yet he conducted all his operations when acting in the latter capacity with the utmost skill, constantly bringing to bear on every difficulty resources which could hardly have been available to any one who had confined his attention to military engineering pure and simple. On the conclusion of the war, our author laid down the sword and took up the level once more, if we may use the phrase, and he has returned with renewed energy to the study of civil engineering subjects. The volume before us is the last which he has written, and we may state at once, and without further preface, that it is, considering its comparatively restricted dimensions, the best treatise on roads and road-making that has ever been published. One of the most noteworthy features about the work is that our author appears to have forgotten nothing. We have searched carefully through the work for omissions, and we have failed to find them. Of course, there are branches of his subject on which he might have enlarged; but on the other hand, all that he says is said to the point and with a purpose, in terse, grammatical language, marked, and to English ears disfigured, it is true, by Americanisms, but never obscure, doubtful, or prolix.

The object of the work, as stated by General Gillmore, is "to give within the compass of one small volume such descriptions of the various methods of locating country roads, and of constructing the road and street coverings in more or less common use at the present day, as will render the essential details of those methods, as well as certain improvements thereon, of which many of them are believed to be susceptible, familiar to any intelligent non-professional reader; to make practical suggestions with respect to the selection and application of materials, and to institute a just and discriminating comparison of the respective merits of the several street pavements now competing for popular recognition and favor." We have slightly condensed the foregoing passage from the author's preface. It shows very clearly what the scope and purport of the work are. It would be impossible in the limited space at our disposal to deal fully with the work; nor is it necessary that we should, as its modest dimensions render it available to every engineer. We may say, in brief, that, beginning at the beginning, General Gillmore not only details every step that is to be taken in laying out and constructing a road, but that he supplies much valuable and interesting information which has never before been made public in this country, and that he suggests systems of construction which are extremely ingenious and economical. The chapter on culverts may be cited as an example. The method of constructing culverts in concrete there described is, we confess, quite new to us, and we believe that it will be equally new to most of our readers. The different classes of roads used in the United States—many of them quite unknown here—are carefully described, and this portion of the work cannot fail to be useful to colonial engineers. Considering the condition of the English oyster market, a recommendation of oyster shells as road-making material sounds strangely; yet General Gillmore tells us that on the sea-board of the South Atlantic and of the Gulf, stone and gravel cannot be had wherewith to make roads save at prohibitive prices, but that oyster shells can be had in any quantity for about five cents per bushel; and that when laid in a coating ten inches thick on a properly prepared surface, they form an excellent road for light traffic, and that when properly maintained such highways "possess most of the essential requirements of a good road." In the United States they use strange materials for road making, and our author describes a charcoal road, made through a swampy forest in Michigan of this material, produced on the spot by burning the timber felled to clear the track. "The charcoal was found to pack well, not to form ruts, nor get soft and spongy in wet weather." The cost was $660 per mile.

General Gillmore's opinion on the subject of street pavements must be regarded as of the utmost value, and we shall conclude this brief notice of his work with a summary of these opinions. He is opposed, on the whole, to the use of wood pavements on sanitary grounds. The best pavement for streets of ample width

and light traffic—such, let us say, as Regent street—is continuous asphalt for all gradients not steeper than one in forty-eight or fifty. But the best pavement for the dense and heavy traffic of a populous city is one of rectangular stone blocks set on a foundation as good as concrete; and the next best is one of Belgian blocks set in the same manner. For further information on this important subject we must refer our readers to the work itself. The volume is well printed, on good paper, and is creditably got up. We must add, however, that the woodcuts with which it is illustrated are by no means up to the usual high standard of American book illustration.—*The Engineer.*

MISCELLANEOUS.

CENTENNIAL EXHIBITION.—The Franklin Institute of the State of Pennsylvania, for the promotion of the Mechanic Arts, through the kindness of the Centennial Commissioners, has opened a Reception Room at the north-western end of Machinery Hall for the use of its members and visitors from abroad interested in the Mechanic Arts. The Institute cordially invites all who desire to do so, to visit their room, in which will be found files of the Journal of the Institute and other periodicals devoted to the Industrial Arts. The room is in charge of a committee of thirty members of the Institute, one or more of whom will be in attendance daily, during the Exhibition, to receive visitors and give any information they may desire in reference to the Exhibition.

The following objects of great historical interest have been placed in the room :

1st. *Franklin's Electrical Machine.*—This instrument is doubtless the one used by the great philosopher in making his wonderful experiments in the science of electricity. Presented to the Institute by Dr. John R. Coxe.

2d. *Oliver Evans' Steam Locomotive Engine.*—This interesting model is among the earliest known, having been built about 1804.

3d. *Oliver Evans' High-Pressure Steam Engine.*—This is the model of an engine built by O. Evans about 1804, and is described in Galloway's work on the Steam Engine, page 101.—London, 1827.

4th. *Working Model of a Steam Engine* built by M. W. Baldwin, and presented by him to the Institute, about 1832.

STREET PAVING AND CLEANSING.—A report on this subject has just been issued by a Committee of the Society of Arts, which has been collecting information for some time past. A good deal of trouble was taken to obtain useful results, as may be judged from the fact that not only was a series of practical experiments instituted to decide the question as to the best of the systems of paving now before the public, but a form of questions was drawn up and left at houses and shops in roads where experimental tracts of new pavement—asphalt and wood—had been laid down. It appears to have been difficult in many cases to obtain answers to this sort of voluntary catechism, but a good many replies were sent in, and the summary of them appended to this report must be taken as a genuine expression of opinion as far as it goes.

The experimental tests, which were made with a specially constructed dynamometer and an omnibus, more or less heavily weighted, resulted in favor of the asphalt, though even this was beaten by a perfectly level piece of granite by the side of a tram. Smooth as the surface of the asphalt appears, it is nevertheless slightly undulating from inequalities in the foundations, and the little slopes thus formed add materially to the amount of tractive force required. The wood pavement was next to this in point of ease of draught, well-laid Macadam being the next best. As to wear, a curious fact is noted about asphalt, that though the thickness of a layer exposed to constant traffic decreases considerably, its density increases in the same proportion, and from this it is argued that there is little or no abrasion from the surface, but that the material is merely compressed, and so actually strengthened by wear. That the asphalt pavings in London have not realized the expectations with which they were laid down is certain, but, according to the authors of this report, the cause for such a state of things is to be looked for in the improper treatment asphalt roadways have received rather than in any defects of the material itself. The obvious defects of asphalt is its slipperiness, and it is now pretty generally known that this slipperiness does not exist when the asphalt is clean, whether it be wet or dry. The only way of keeping it clean is by constant washing, and no suitable means exist for this; besides, when the roadway was plentifully besprinkled with water, such serious complaints arose of the "slop" that the watering was stopped.

The objections put forward against wood pavement are chiefly sanitary. It is stated that the wood readily absorbs any liquid refuse left on the surface, and thus becomes a dangerous source of infection, while it retains wet for a long time and is difficult to clean. These conclusions, it is but fair to remark, seem to have been arrived at from a consideration of the older systems of wood pavement rather than from any extended examination of the newer methods now apparently increasing in popularity.

The actual damage also from dust—dust, it must be remembered, consisting of particles of horse-dung, sharp particles of granite, and even morsels of iron—is an appreciable quantity; while the question of injury to health, mental and bodily, from the unceasing clatter of streets is not to be neglected. These and many other such like obvious considerations are sufficient, if any reasons were required, to urge the adoption of some good and uniform scheme for our London pavements. But if the construction of good road-ways is all-important, hardly less requisite is the adoption of some proper method of cleaning them. For this purpose the use of a jet is strongly urged, on the ground that the jet, when properly applied, may serve the purposes both of a watering-cart and broom, while it is also capable of washing courts, alleys, and walls. Whether we shall ever see the familiar watering-cart superseded by some such appliance as that in use in Paris for distributing water over the street from a hydrant is perhaps questionable. At all events there are strong arguments in favor of the foreign plan.